ORTHOPÆDIC EFFECTS OF GUNSHOT WOUNDS AND THEIR AFTER TREATMENT

S. W. DAW

OXFORD
WAR PRIMERS

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ORTHOPÆDIC EFFECTS OF GUN-SHOT WOUNDS AND THEIR TREATMENT

BY

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WITH A FOREWORD BY

MAJOR-GENERAL SIR ROBERT JONES, C.B.

AND APPENDIX ON FUNCTIONAL DISABILITIES BY

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PREFACE

It is hoped that this little book may serve as a useful introduction to the treatment of the Orthopædic Effects of Gunshot Wounds. It embodies the results of experience gained and the methods which have been found most serviceable in actual practice at the Second Northern General Hospital, Leeds.

The Author wishes to express his grateful thanks to Major-General Sir Robert Jones for much kindly advice, to Captain Burrow and Dr. Cuthbert Morton for help in revision, and to Lieutenant-Colonel Littlewood, Administrator of the Hospital, for permission to make use of the clinical material and records of the Hospital.

Many of the illustrations are available through the courtesy of the Hospital staff and Messrs. Vizard, Ltd., Surgical Appliance Makers, Leeds.

S. W. Daw.

FOREWORD

THE Surgery of this War has brought about many modifications in practice and theory, and has made it necessary that every medical man should be prepared to solve problems which in other days were left to the few. A work such as this, written simply and lucidly by an author of skill and experience, will prove very useful to many surgeons. We can scarcely visualise yet the many thousands of cripples who for a generation will be distributed in town and village, nor the great demands which will be made upon the surgical resources of our profession. Even now, after long years of war, the preparation for the reception of our discharged men is wholly inadequate. The country will shortly be flooded with men who deserve and will demand the most skilled treatment that the nation can afford. An immediate effort should be made to secure for the discharged soldier after the War many of the Orthopædic Centres which are now under the jurisdiction of the War Office. Delay in doing this will mean disaster, and will result in a just and bitter resentment on the

part of our people. The question of finance should be a secondary one, and is of trivial importance when compared with the economic potentialities of physical and mental reconstruction.

The establishment of Military Orthopædic Hospitals, now termed Special Military Surgical Hospitals, has allowed of many opportunities for widening knowledge, and improving the methods of treatment of war wounds. The segregation of orthopædic cases in these centres has enabled surgeons to concentrate their energies on reconstructive work. By instruction given at the various centres, the general surgeon has been enabled to extend his knowledge and increase the usefulness of his treatment. Special stress has been laid on such subjects as Nerve Suture, Tendon Transplantation, Bone Grafting, as well as the various special modes of treatment by massage, baths, electricity, manual exercises, etc.

Captain Daw has wisely used his experience to appeal through this manual to a wider audience, and there is no doubt that its perusal will benefit those for whom it is written. I heartily wish it every success.

ROBERT JONES.

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INTRODUCTORY NOTES

Orthopædic Effects of Gunshot Wounds.

The gunshot wounds of the present war have brought into prominent view an aspect of orthopædic surgery which was previously unfamiliar to the majority of the medical profession. From the standpoint of deformity and consequent disability the principles of treatment hardly differ at all from those concerning the orthopædic troubles of civil life, but whereas the latter have, as a rule, presented no special difficulties beyond those of the deformities as such, in the present circumstances nearly every case is complicated by suppuration which has often been prolonged and has led to the formation of scar tissue, often of great extent, to massive adhesions of otherwise uninjured soft parts, to infective osteitis and arthritis and to disturbances of circulation.

Moreover, the lesions are frequently complex, in that there may be in the same case injuries of blood vessels, nerves, bones, joints and muscles. Problems of the greatest difficulty may, therefore, present themselves for solution even if the previous suppuration might be considered to have died down entirely. Unfortunately, sepsis has still to be reckoned with in every case. No matter how long

a time has elapsed since suppuration ceased, nor how well healed the wound appears to be, the danger of recurrence is always present. This may be stimulated into activity by such a simple application as radiant heat or massage. Greater disturbance, such as that of passive movement of a joint or an open aseptic operation, involves greater risks. How much greater still, if the operator through some slip in technique allows fresh germs from outside to come into contact with the tissues! The process of suppuration once started, it may flare up as widely as ever and an otherwise brilliant operation be entirely spoilt, even if the patient's life or limb be not endangered.

These remarks are to serve as a warning and not as a discouragement. By the exercise of proper care open operation can be performed with the prospect of primary union, and the lesser procedures can likewise be carried out without undue risk. Above all is it necessary to eschew the pernicious doctrine that because a case is septic, therefore aseptic precautions are needless or may be relaxed. They are necessary and doubly necessary, and any carelessness of technique is a surgical crime of the highest degree.

The results of treatment have been most encouraging. Many cases have been cured, many have been relieved by simple appliances and enabled to return to their former employment, and many have been set on the high road to recovery, though the road may be a long one.

With these last it is most important that suitable occupation should be found. Nothing can be more dreary or demoralising than a long stay in hospital with nothing to do but to kill time. At many orthopædic centres workshops have been opened as a method of treatment. Here employment is found suited to the individual needs of the cases. A man with a stiff ankle works at a treadle machine, another with a stiff arm is employed at a carpenter's bench, others whose muscles do not co-ordinate and need re-education are given such work as will lead to improved control in the defective muscle groups, and so on.

Sometimes an indirect method of attack is more useful—for instance, a patient with some stiffness of the lower limb is given some manual work which will occupy him in the standing position and induce him to use the affected lower limb unconsciously.

A department of massage and electrical treatment is essential, and nearly every case must be sent there during part of his stay in hospital. A certain number of machines for active remedial exercises for weak muscles and stiff joints are a valuable adjunct, but these should be of a simple character and used for selected cases. Purposeful exercise with an ultimate object such as that of the workshops is much more satisfactory and less tedious.

Radiant heat baths, swirl baths, and hot paraffin baths are valuable in improving the circulation in association with massage and electrical stimulation. Neurological examinations may be undertaken best

after these various kinds of treatment, as sensation is improved and electrical excitability increased to a more normal condition by improvement of circulation, which usually tends to be defective in cases of nerve lesions. In connection with the subject of massage, a reference must be made to passive movements. It is commonly understood among operators in massage departments that when massage is ordered, passive movements of stiff joints is part of the procedure. This view should be firmly combated. It is a good working rule for use in connection with a massage department that passive movements should not be applied to a joint if there is anything the matter with it. If the stiffness is of soft parts only, little harm is likely to be done in cases of long standing by passive stretching. But if there is some intrinsic trouble in the joint, much harm may be done by well-meant but ill-timed efforts at mobilising a joint by some one who has not even the limited knowledge of the surgeon as to the actual condition of the interior of the joint, and who may by injudicious to and fro movements increase the ultimate limitation of the joint movement instead of diminishing it. Passive movements, therefore, should never be given unless ordered, and should always be ordered when desired.

Stiffness of Joints.

This may vary in extent from slight limitation of one or more movements only to a complete bony ankylosis. The treatment of each particular joint

is dealt with later. Here a few general remarks will suffice.

The interference with movement may be due to—

(*a*) Damage to the elements of the joint, especially the articular cartilages, which may be more or less destroyed.

(*b*) Contractures or adhesions of soft parts crossing the joint, particularly ligaments, muscles, or skin, any of which may be injured and replaced by scar tissue. The contracture or adhesion may be either over the joint or at some distance from it, as in the case of adhesion of muscles to the shaft of a bone.

(*c*) A mechanical block in the way of movement, usually of a bony character, due to traumatic myositis ossificans, displacement of fragments of bone, excessive callus, or unreduced dislocation.

(*d*) Reflex muscle spasm from pain due to incomplete healing of an injury either inside or outside the joint.

Inspection may at once show the nature of the interference, as in the case of a contracted scar across the front of the elbow. Flexion may be complete, but extension will cause dragging on the scar. In other cases the position of the scar or a deformity of the joint will point to the cause of the limitation. A gentle attempt at passive movement of the joint may reveal much.

Even if the joint is without any range of movement, the difference between bony and fibrous ankylosis can usually be detected. In the former the rigidity is absolute, in the latter it is relative;

there is a slight spring in the joint, and a firm attempt at movement may cause pain.

In the same way with limited movement it can usually be ascertained whether the obstruction at a certain point is due to a bony block, or to the resistance of soft parts. In the one case movement will come to a sudden and absolute stop in one direction, while movement in the opposite direction may be unaffected. In the other case resistance may become greatly increased at a certain point beyond which there is a sensation of springy recoil, and the tension may be painful.

Limitation due to pain and consequent muscular spasm is of a different character. The resistance is more elastic, and is associated with visible contractions of the controlling muscles and a complaint of pain before a point of definite stoppage is reached.

An examination by X-rays and scrutiny of the negatives should be made in all doubtful cases.

In bony ankylosis the joint cavity may be found completely obliterated. In other cases there may be seen a general haziness of the joint outlines or merely a narrowing of the space between the shadows of the component bones indicating the partial destruction or thinning of the articular cartilages and a condition of fibrous ankylosis.

With less severe lesions the joint may appear hazy at one point only, suggesting at most a partial fibrous ankylosis and the hope of obtaining a considerably increased range of movement.

The above may be termed regular types, but

sometimes smashing has been so severe as to destroy all semblance of a joint, and to leave irregular bony masses in apposition. Such cases may require treatment as though bony ankylosis were present.

In the case of bony block the joint may appear normal, but a shadow of abnormally placed bone will be seen near the end of one of the bones forming the joint.

If the joint seems to be in every way normal in careful comparison with the corresponding joint of the opposite side, it must be assumed for purposes of treatment that the trouble is extra-articular.

The precise method of treatment of the different conditions varies with different joints, but speaking generally—

Bony Ankylosis will be treated by an open operation to mobilise the joint, or to place it in the most advantageous position of stiffness.

Fibrous Ankylosis is subjected to gradual stretching by splints in the hope of reducing deformity and increasing the range of movement. If this fails, it may need similar treatment to bony ankylosis.

Partial Fibrous Ankylosis will probably yield to gradual stretching, or, in suitable cases, to manipulation into a better position.

False Ankylosis from scarring of soft parts receives very similar treatment. The outlook of manipulation is better, however.

Contracted Scar may be excised or stretched gradually.

Bony Block will usually lend itself to removal.

Limitation from Muscular Spasm will, as a general rule, indicate rest for the joint until pain and spasm have disappeared.

Manipulations of Joints and Passive Movements.

It is convenient to reserve the term Manipulation for set proceedings by the surgeon to improve position, or to break down adhesions under general anæsthesia; and to describe as Passive Movements such daily or periodic measures as are needed to maintain a range of movement already gained.

It is highly undesirable that either of these should be regarded as a routine procedure for joints with defective range. Each should be undertaken only after due consideration of the probable results and with a definite object in view. No amount of moving roughened joint surfaces over each other will help to make them work smoothly; in fact, the effect will be just the reverse. Raw bleeding surfaces will be left where the articular surfaces were previously adherent, and these in healing will lead to adhesions even stronger than before.

When, therefore, there has been an injury of the articular cartilages, *i. e.* a traumatic or septic arthritis, the prospects from manipulations of any kind are limited.

In these circumstances manipulation may be undertaken with one of two objects—

1. To correct a deformity and put a joint into a more useful position. For example, a knee joint may have a range of 10 degrees, from 130 to 140

degrees, and be comparatively useless. If the knee is fully straightened and loses the small range of movement, it will be much more useful. It may be found, however, that a small range of movement is still retained, viz. from 180 to 170 degrees, which will give in time a good walking leg. In such a case the value of the manipulation is obvious.

2. To increase the range of movement. The sticking together of the articular cartilages may be only at one point. In such case movement of a joint to a fresh position will bring the raw surfaces out of touch with each other. Each raw surface will now be in contact with healthy cartilage, and the adhesions which form will be of a less serious nature and may be dealt with at a later date with good result. In more widespread conditions of intra-articular adhesion more will usually be gained by continuous stretching, as by the Turner and other splints (see p. 55). Even in these cases manipulation may help, but only on the principle of being content with a small movement, say of 10 or 15 degrees, and then resuming the continuous method. By such cautious means much may gradually be gained where drastic measures would probably fail. As the range of movement is thus being developed the patient may be encouraged to assist by voluntary movements, but it can be seen that passive movements have no prospect of doing good here, and should be avoided.

In the other great class of stiff joints, namely, those in which limitation of movement is due to

surrounding conditions and not to damage of the articular cartilages, the prospect of increasing the utility of the joint is considerably greater. The obstruction in such cases may be due to contraction or adhesions of synovial membrane, ligaments, tendons, muscles or skin, or to a mass of scar tissue following the damage of any of these structures. Reference has already been made to the treatment of scars involving the skin by excision or stretching. The other conditions, in which the skin is intact, can usually be distinguished from those of arthritis from the fact that in the case of adhesions and contractures outside the joint it is rare for all movements of the joint to be restricted. For example, a hip joint may show limitation of extension and abduction, yet if rotation is free it is certain that the articular cartilages are not seriously involved. Again, an elbow may be resistant to both flexion and extension, but pronation and supination may be free. In this case it is clear that the radio-humeral and superior radio-ulnar joints are not affected, and, apart from definite findings, it is probable that the trouble is extra-articular.

Such cases lend themselves to manipulation for the breaking down of adhesions. Before this is undertaken it is essential that the wounds should have been soundly healed for some months, for fear of lighting up suppuration, and that precautions are taken against producing or reproducing a fracture. In cases where great resistance is expected, or where there has been a fracture of an adjoining

bone, it is always advisable to apply moulded gutter splints (Fig. 1) to the whole length of the adjacent bones. The technique of manipulation of each joint is described later. The movement should be carried out by steady continuous pressure, and not by jerky muscular efforts, as the latter are inefficient, and may cause harm by setting up undue irritation, or may even produce fracture. It is best so to arrange the limb that the force can be applied

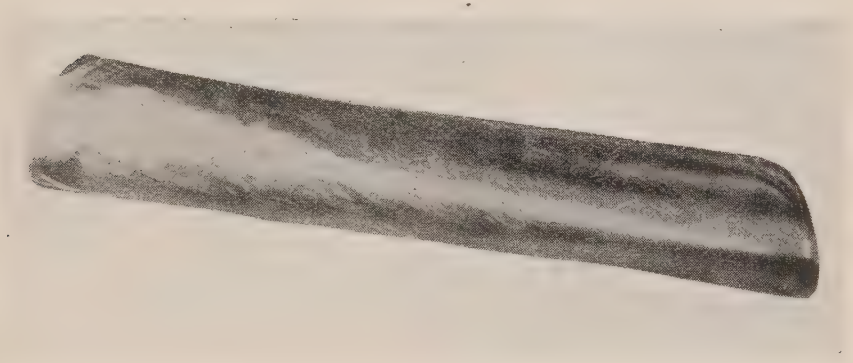

FIG. 1.—GUTTER SPLINT.

by the weight of the surgeon's trunk rather than by the power of his arm muscles. It is less exhausting and less dangerous to apply with reserve a force which is well in excess of the task required of it.

In the cases under discussion, namely those of extra-articular adhesions, it is important to carry the joint through its whole range of movements. Under all conditions this should be done once only at a time. Nothing is to be gained and everything to be lost by repeating the movement more than once.

No definite rule of after-treatment can apply to every case. When the original damage has been of a mild character, causing such a light obstruction as can be dealt with under gas anæsthesia, the patient should be told to put the joint through its full range as soon as he recovers consciousness. This will give him confidence and assist in future movements. This is the class of case for judicious passive movements. On the following day the joint should be moved gently through its entire range once only, and then allowed to rest. On the next day again the conditions are observed. If pain is less and movement greater, active and passive movements may be proceeded with on the same lines.

If pain is greater and movement less, it is a sign that further rest is required. Massage and baths, etc., may be used daily, but passive movements must be deferred until the inflammation has subsided, as shown by reduction of pain.

In the conditions of war injuries the obstruction to movement is more serious in its character in many instances than in the class of case just referred to. When difficulty is expected ether anæsthesia is advisable, as there is more complete relaxation of muscles and more time to carry out the manipulations. The amount of inflammatory reaction is greater, and it will usually be found that following daily passive movements through a full range are out of the question. In such circumstances the joint should be put at rest, generally in a position as remote as possible from that which was present

before the manipulation, and which was probably a faulty one. In the elbow, for example, the usual pre-existing condition is one of full stiffness, or a small range round about 120 degrees. Manipulation will consist chiefly of flexion. The joint is put at rest in as full flexion as is practicable for circulatory reasons. If passive movements of extension from this position are painful on the following day, the wrist is kept slung to the neck for four or five days. The sling is then dropped slightly to allow a small range from full flexion. If after a day or two this range can be actively carried out, a small further range is allowed, and so on to a full range of movement. If the relaxation leads to greater stiffness, it is a sign that it is premature, and the joint is rested in full flexion for a further period. In other cases with less pain, it may be possible to change the position daily from one of flexion to one of extension, with rest in the intervals. The Turner Splint described later (p. 55) may prove useful in such circumstances.

The position of Passive Movements as a means of treatment has been indicated in the foregoing remarks—

(*a*) In the presence of injuries of the joint surfaces they are of little, if any, value, and, indeed, are usually harmful.

(*b*) In the case of extra-articular lesions they are useful to maintain a range of movement already gained, rather than as a means of increasing the range of movement. When used they should carry the

joint once, and once only, through the range permitted, and should not be repeated during a period of inflammatory reaction. As will be seen later, they are also of value in cases of nerve injury to prevent the formation of adhesions which may be very crippling and difficult to remove when they are once formed. A normal joint will never become permanently stiff through being kept at rest, but there are in nerve lesions certain trophic changes which affect soft parts, cartilages and bones, so that the joints in such cases cannot be regarded as normal.

As regards voluntary, as opposed to passive, movements, they are nearly always valuable, and rarely harmful in the class of late cases coming within the scope of this work. Use of a partially stiffened joint, whether in a remedial gymnasium, a curative workshop, or in a civil occupation, will in time often lead to a better result than can be reached by any of the means previously discussed. It is obviously undesirable to keep a patient in hospital for a day longer than his treatment requires, and it is hoped that this book may serve to indicate both the extent and the limitations of the possibilities of surgical treatment.

Mal-united and Ununited Fractures.

Mal-union.—With regard to mal-union of fractures it should be kept in mind that an anatomically perfect result after a fracture is rarely possible, except by open operation. Such a result is not necessary. If there is union without interference

with function or appearance, the union may be regarded as clinically perfect. For practical purposes the degree of mal-union is that of interference with full function. The effects of mal-union may be seen in—

(*a*) Shortening from overriding of fragments or angulation.

(*b*) Faulty alignment, leading to strain on joints from disturbance of the lines of weight bearing, to weakness of muscles from interference with their lines of pull, and to limitation of movements of joints from projection of fragments in their neighbourhood.

(*c*) Rotation deformity, which may cause disabilities of much the same kind.

(*d*) Interference with muscles or nerves from excessive callus formation.

The treatment is discussed in connection with the injuries of the individual bones, but a few points need special attention.

1. That in cases of gunshot wound fracture the condition has been compound and usually with serious and prolonged suppuration. Any open operation is, therefore, to be avoided if possible, and if it is inevitable it should only be undertaken after wounds have been healed and suppuration has ceased for perhaps six months or more. Before such an operation is performed the soundness of healing should be tested by a course of radiant heat and vigorous deep massage. If there is no reaction of inflammation, the operation may be proceeded with,

but often these simple stimuli will lead to the usual signs of inflammation and the breaking down of scars, which will indicate that the time for operation has not yet come and that it must be deferred for some months.

2. That the deformity from mal-union may, for some time after apparent union, be reduced with comparative ease by manipulation. Tenderness at

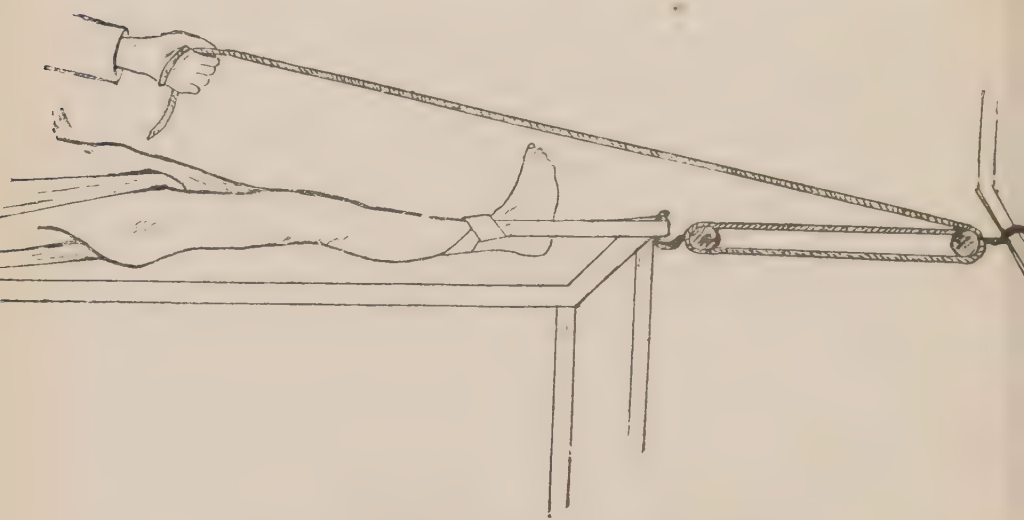

FIG. 2.—BLOCK PULLEY EXTENSION.

the site of union and pain in testing the firmness of union are signs that the callus is still soft and will yield to forcible movement. At this stage, therefore, faulty alignment, angulation, or rotation deformity should be corrected under ether anæsthesia. Overriding fragments may be disengaged and extension may be applied first by block pulley under the anæsthetic (Fig. 2), and later during fixation in a splint. It has been seen that massage alone

will stir up suppurative processes, and it is hardly necessary to give warning against a similar danger after forcible correction. Any correction made before healing of wounds is complete must, therefore, be of the simplest and gentlest nature. Union after these corrective measures may be promoted by the use of percussion and damming, as in the case of Non-union, *q.v.* The correction obtained by manipulation may lead to a sufficiently good result, but if not it will very greatly reduce the severity of any open operation subsequently needed.

3. That when open operation is necessary it should be of the simplest character compatible with a good functional result. Faulty alignment, angulation, or rotation deformity may often be cured by a linear osteotomy, which may be made in some cases through the old fracture, while in others it is equally effective and safer to make it through healthy bone near but not at the site of the united fracture. More severe deformities may call for the removal of a wedge of bone—a cuneiform osteotomy. In cases of overriding it may be possible to separate the fragments with an osteotome or osteotomy saw, after which pulley traction is applied. The subsequent treatment after osteotomies is that of a recent fracture. Only in cases of great deformity will it be necessary to expose the fragments and secure in end-to-end apposition with a Lane plate or bone graft.

Non-union.—Delayed or absent union after gunshot wounds is nearly always due to local causes. The

patients are chiefly young and otherwise healthy adults. Suppuration with local necrosis is a common cause. In the majority of cases healing of the wound precedes union of the bones, but by no means in all. However, the problem of non-union does not present itself as such while suppuration is still going on. Treatment is first to be directed to the healing of the wounds, while fixation in a correct position is maintained.

Loss of bone substance is frequently the chief factor. The broken ends may not reach each other, or, if they do, they may have been tapered by smashing and suppuration to two fine points which may meet or overlap, but without any prospect of affording firm continuity of the shaft.

Overriding of well-shaped fragments usually leads to feeble mal-union, which is discussed under that heading.

In other cases the fragments are of good shape and in sufficiently good apposition, and yet union does not take place after healing of the wounds. In these circumstances defective immobilisation and extension or interference with circulation by pressure of plaster, splint or tight bandaging may be very important factors in delaying union.

X-ray negatives in two planes should be taken in all cases.

If good apposition is present, treatment is on the following lines—

(*a*) Suitable measures to induce healing of the wounds or sinuses.

(*b*) Efficient splinting, with extension to maintain immobility, length, and good alignment.

(*c*) Removal of circular compression so as to allow good circulation.

An interval of two months may be allowed under these good conditions. If there are still no signs of union, osteogenesis should be stimulated by percussion and damming, according to the method advised by Thomas.

Under anæsthetic the fragments are pointed toward the skin and sharply tapped with a mallet. Pieces of rubber tubing are then tied round the limb three or four inches above and below the site of fracture, and the splint and extension reapplied. The rubber tubes are then untied and left in position between the limb and the splint, ready to be tied from time to time without disturbance of the limb by their reapplication (Fig. 3). These should be tightened each day, beginning with half an hour and extending the time gradually until they can be tolerated for several hours a day. They should be tied tight enough to produce definite venous congestion with swelling. This treatment will usually induce callus formation in a few weeks. If at the end of a second period of two months there is no response, operative interference is indicated.

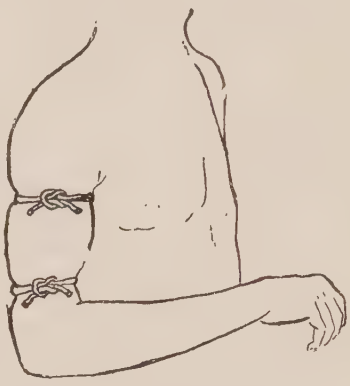

Fig. 3.—Damming.

If apposition is bad other measures are likely to be needed.

1. Overriding is treated as in early mal-union, percussion and damming being also used.

2. A gap between the ends may sometimes in the case of a single bone be obliterated by relaxation of extension to allow the ends to come together. With large gaps the alternative of bone-grafting must be seriously considered. In the case of a small gap in one of the bones of the forearm, the gap may sometimes be obliterated by resection of a suitable portion of the accompanying intact bone. In the majority of cases, however, a bone-grafting operation is more usually needed.

3. Tapered fragments will almost certainly need bone grafting.

Bone Grafting and Plating.

Speaking generally, bone plating is used to immobilise the broken fragments of a bone in a good position. A bone graft may be used for the same purpose, though it is usually slightly less efficient, but it has the additional object of aiding new bone formation by the introduction of fresh osteoblasts, or of bridging a gap in the continuity of a bone. Thus, in cases where there is no loss of bone, the ends may be freshened and brought together and retained in position by either method. Where, however, there is an actual gap to be filled, some form of bone graft is essential. The graft itself can usually be made to attain the required fixation, or in some

difficult cases the two methods may be combined, the lost bone being replaced by a graft and the fixation obtained by a metal plate.

Neither operation should be attempted without the full complement of necessary instruments and the highest degree of asepsis. The surgeon must be prepared to carry through the whole operation without the introduction of the hands, however well sterilised, into the wound. The operations are infinitely easier to perform in this way and asepsis is as far as possible insured thereby.

Gloves, masks, and caps should always be worn, the first-named being put on after carèful preparation of the hands. The outside of the glove must never be touched by the bare hand in the process.

The skin of the patient, however carefully prepared, must not be touched by the glove in making the primary incision, which should always be of ample length. The incision made, the skin knife is laid aside and not used again. Fresh sterilised towels are now fixed to the edges of the skin wound, so as to shut off the surrounding skin from the raw surface exposed. The site of fracture is opened up with a fresh knife and long periostel elevators. Special bone-holding forceps are used to bring the fragments into line and keep them there during the application of the plate or graft. Special forceps are to be used for holding plates and screws during their application. Space does not permit a full description of the technique to be employed in the plating of bones. In brief, the essentials to successful operations are—

(*a*) The completest asepsis.

(*b*) The full complement of specially designed instruments.

(*c*) Adequate assistance.

(*d*) A thorough working knowledge of the particular manœuvres to be used. Unless there is loss of bone, no result should be considered satisfactory which does not attain practically full restoration of length and alignment.

The Methods of Bone-Grafting.

All the precautions which are insisted on for bone-plating are equally necessary in grafting of bone. Reference must now be made to the methods of procuring and placing grafts. The objects have already been indicated, and are—

(*a*) The fixation of fragments.

(*b*) The aiding of osteogenesis.

(*c*) The filling of a gap in continuity.

Bone grafts may be—

1. Heterogenous, being taken from another species.
2. Homogenous, from another of the same species.
3. Autogenous, from the individual operated upon.

The last class only will be considered here, as being the most satisfactory, both as regards the simplification of the operation and the better prospects of successful grafting.

Generally speaking, the graft may be taken from the fractured bone in cases where there is no loss of substance, whereas, on the other hand, when there is a gap to be filled the shortage of material is best

met by taking the graft from another bone, usually an uninjured tibia as a matter of convenience.

Two methods are commonly employed—

(*a*) An inlay graft (Fig. 4), the graft and its bed being prepared with the use of the Albee parallel circular saws.

(*b*) A lateral graft, by preparing a raw surface on one side of the fracture and bridging the fracture

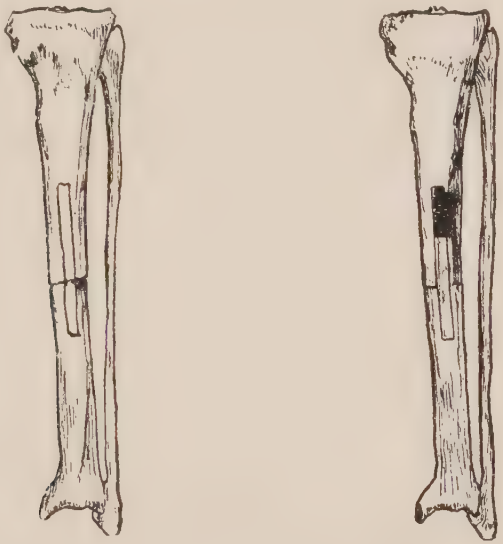

FIG. 4.—INLAY BONE GRAFT.

with a portion of shaft detached and slid across the fracture, or by using a portion of another bone for the same purpose (Fig. 5, p. 37).

Further details of the methods are given under the head of Fractures of the Tibia, *q.v.*

Causes of Failure of Bone-Grafting.

Bone-grafting operations after gunshot wounds have been by no means so successful as in civil

practice. Greater experience has shown the causes of failure and how they can be avoided.

Non-success may usually be attributed to—

(*a*) Damage to the graft.

(*b*) Imperfect nutrition.

(*c*) Incomplete immobilisation.

Damage to the graft may be due to rough usage, long exposure, overheating by Albee saw, or washing after removal. A stream of warm saline must be poured on the graft during the cutting with the Albee saw to prevent overheating; but once the graft is cut and removed it must be at once placed in its prepared bed without being laid in saline solution, which would tend to wash away the osteoblasts. It must be fixed in its place so firmly that there is no appreciable mobility at the site of fracture.

The use of a lateral Lane plate is sometimes needed to attain this degree of fixation. Careful and complete splint immobilisation is needed for at least twice as long as in the case of an ordinary fracture before the question of union is even considered.

As regards faulty nutrition this may be due to suppuration, collecting of blood round the graft, or to its lying in imperfectly nourished tissue. Suppuration must be avoided by a careful choice of the time of operation, and by the most rigid asepsis during its performance.

Hæmostasis must be assured before the wound is closed. All bleeding points must be carefully secured, and swabs soaked in hot saline solution must be packed into the wound and the bed of the graft during the

preparation of the latter. The use of the tourniquet is clearly contraindicated.

As the graft must necessarily cross the scar, the size of the latter must be seriously considered before the grafting is undertaken.

Frequently there has been sheer destruction of a side of the limb, and if the graft is laid in the large resulting scar there are no good prospects of satis-

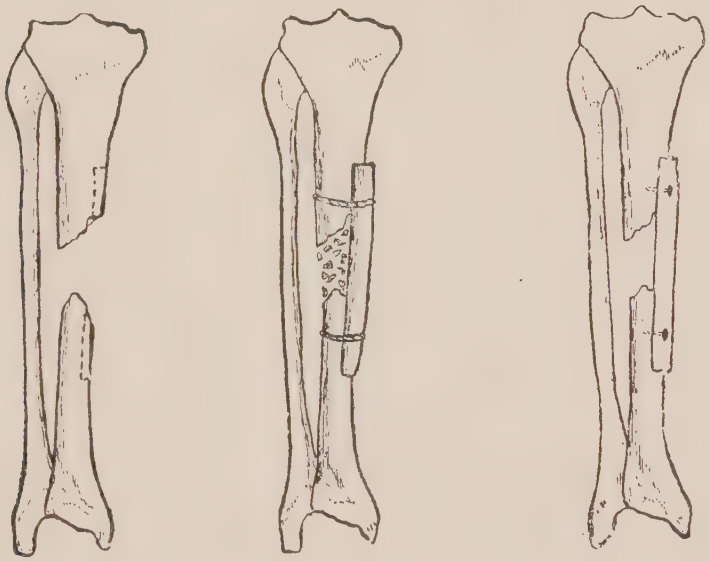

FIG. 5.—LATERAL BONE GRAFT.

factory nutrition. For this reason a preliminary excision of the scar is usually needed. The result in the healing after this operation will be a useful guide as to the suitability of time for bone-grafting. If soft parts cannot be brought together a plastic operation of some kind must be performed to close the wound. In the case of the upper limb a good flap may be taken from the trunk in the manner

described in connection with scars in the flexure of the elbow (p. 57).

Procedures of this kind will very greatly improve the chances of a subsequent bone-grafting, and will indeed save a good deal of time in the long run.

INJURIES OF THE UPPER LIMB

Fractures of the Clavicle.

Mal-union is common from the anatomical standpoint, but is hardly ever of such a degree as to interfere with function. No special treatment is therefore required.

Non-union may occur from destruction of bone, from deficient immobilisation, or from overlapping of fragments. If the apposition of fragments is good a reasonable time, say three months, of the best possible fixation, should be allowed to ascertain if it is a case of merely delayed union. Otherwise an operation should be performed to fix the fragments. There are no special difficulties. The front and upper surface of the bone are exposed—by a flap if possible —and the ends of the bone at the site of fracture are freshened. Fixation may be made by a Lane plate or bone graft. If the plate is used it should be thin and should be moulded to the shape of the bone. It should have two holes at each end. In the case of grafting, a piece from the tibia may be taken to be used as an inlay or an intra-medullary peg. The arm should be kept at rest in a Sayer or similar appliance until union is firm, perhaps for six weeks, after which time a sling will suffice and gentle active and passive

movements are allowed, with massage. Even if there is shortening, the functional result is excellent.

Dislocations of Either End of the Clavicle.—The joints involved depend for their security very little on the shape of the bones, and almost entirely on the strength of the ligaments.

In cases of long standing, such as are considered here, reduction of the displacement is usually still easy, but the prospect of benefit thereby very small, as the ligaments cannot be restored. Both the sterno-clavicular and the acromio-clavicular joints have been subjected to fixation operations, but the results have been disappointing. Function is usually not improved and may be further impaired in the direction of interference with scapular movements. In other words, a stiff joint is less serviceable than an unduly movable one. In any but recent cases it is, therefore, recommended that the patient should make the best of things as they are by exercises and massage to improve function.

Injuries of the Shoulder Joint.—Mechanically these fall into two classes—

(*a*) Those in which movement of the joint surfaces is restricted.

(*b*) Those in which there is loss of bone, with want of contact between the humerus and scapula.

Cases with Restricted Joint Movements.—These should be carefully examined to ascertain how much of the movement of the upper limb is due to the play of the scapula, and how much to the movements within the shoulder-joint itself. A patient may have

complete ankylosis of the shoulder-joint without being aware of more than a restriction of range of the limb. The scapula should therefore be held as firmly as possible and the scapulo-humeral movement tried passively. Owing to the impossibility of complete immobilisation of the scapula it will be difficult to determine whether ankylosis, if present, is bony or fibrous in character. It may be found that there is only partial limitation of the joint movement. In any case there will be reduction of the ability to lift the arm out sideways, and then vertically. In practically all cases pre-existing conditions have led to the arm being kept at or near the side, so that the normal range of abduction has been lost.

If the wounds are soundly healed and there are no signs of inflammation, massage and abduction and other exercises may be started. Meanwhile X-ray plates are ordered and the case is further considered. Unless definite improvement is brought about within a few weeks, other measures must be contemplated.

The Ideal Position.—As a preliminary to discussion of treatment of stiffness of the shoulder it will be well to define the best position of ankylosis.

With the scapula in its normal vertical position, the humerus should point outwards, also slightly downwards and forwards. This position may be illustrated in a normal person by placing the tip of the middle finger on the middle of the opposite clavicle, and raising the elbow nearly to the horizontal, the wrist being kept straight. In a patient with the shoulder joint ankylosed in this position, the play of

the scapula will allow quite a useful range of movement of the upper limb. With stiffness short of ankylosis, it should be the aim of treatment to include this position in the range of possible movements. The Bandolier Shoulder Splint (Fig. 6) will hold the arm in approximately the best position,

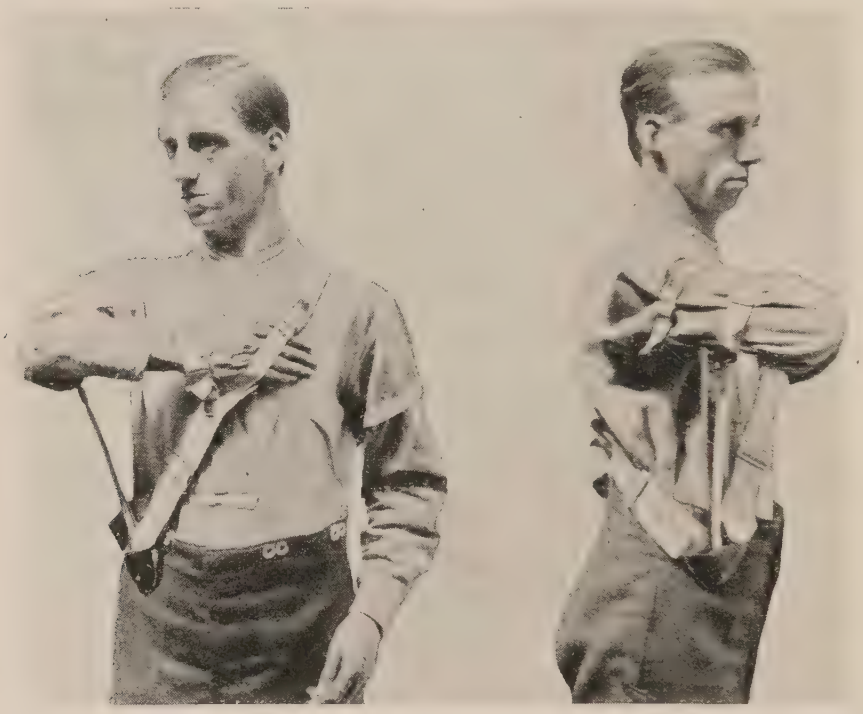

FIG. 6.—BANDOLIER SHOULDER SPLINT.

and whatever splint is used there will be a small margin of error owing to difficulty in controlling the exact position of the scapula.

Bony Ankylosis.—If the patient can, by scapular movements, already raise his arm to the horizontal, the benefit of operative treatment will be relatively

small, and he may well be left as he is. If, however, his range is short of this, a wedge-shaped osteotomy should be performed through a vertical slitting of the deltoid muscle whose function may here be disregarded. The arm is fixed with the humerus at an angle of 70° to the normal vertical position of the scapula, and is kept in abduction on the Bandolier splint until bony union is assured.

Fibrous Ankylosis.—The object is the same as in bony ankylosis, but the procedures to attain it are different. A wedge-shaped osteotomy is not advised here as the weight of the limb will tend to undo the correction made by it.

An attempt may first be made to obtain the ideal position by manipulation under full ether anæsthesia. An assistant should hold the scapula and press upward the head of the humerus, while the surgeon by strong, steady abduction of the arm attempts to move the joint. He should grip the surgical neck, and apply pressure along the length of the inner side of the humerus with his own forearm to prevent undue strain on any one part of the shaft. Gutter splints may well be applied to the humerus before the manipulation is begun. Considerable force may be used, if applied steadily, by the surgeon's body weight, and not by jerky muscular action. It is not enough to get the arm into the horizontal position, as scapular range will help in that. It must be brought to the horizontal when the scapula is in its normal vertical plane, so that later the scapular movements will increase the range beyond the

horizontal. As it is impossible to fix the scapula in its normal position, the arm must be placed after manipulation in as full abduction as possible on the shoulder splint to allow for the play of the scapula and to keep the arm as nearly as possible at right angles to it in the position it assumes.

Failing success by this method, an operation for arthrodesis of the shoulder joint is advised. The joint is exposed through the deltoid muscle and the articular surfaces separated and exposed to view. The remains of the articular cartilage are removed with an arthrodesis gouge, particularly from the end and the outer surface of the head of the humerus, also from the glenoid cavity. The lower aspect of the acromion process is also made raw with the same instrument or a chisel. Holes are drilled and a wire passed through the acromion process and the neck of the humerus at such a position that the head is pressed firmly against the glenoid cavity and the upper surface of the neck against the under surface of the acromion. The shaft of the humerus should be fixed at 70° from the normal vertical of the scapula, and may be further secured in this position by a screw or nail passing through the head into the glenoid process of the scapula.

The shoulder splint must be kept on in its original position for six weeks after manipulation or arthrodesis. The case must be watched during subsequent massage and exercises, and recurrence of adduction guarded against by letting down the abduction a few degrees at a time to be sure that the corrected

position is maintained. At the end of a further six weeks the splint may be abandoned if all goes well.

Other factors maintaining adduction may need attention at the time of the operation of correction, as by excision of an axillary scar with plastic repair or by lengthening or division of the muscles of the axillary folds if involved in scar tissue.

Extra-articular Lesions. — Skiagrams may show that the joint surfaces are normal and that the obstruction to movement is outside the joint. Apart from dealing with scars, etc., as above, the treatment is by manipulation, but in this case in the hope of obtaining a movable joint.

(*a*) If full range of movement is obtained quite easily, no splint is needed, but massage and exercises are used as before. The joint should be put through its full range at suitable intervals under the conditions described in the Introduction.

(*b*) If movement is difficult, the ideal position should be reached, if possible, and the shoulder splint applied for six weeks, during which massage and faradic stimulation may be used with the arm on the splint. After this interval it is let down gradually as described under the previous heading. In this case the prospects of a movable joint are not very good, but time and occupation may do more than might be expected. If adduction recurs in spite of careful treatment, an arthrodesis may be needed. At the worst the patient should have a stiff shoulder in the best position, a good result as regards function.

Limited Movement.—So long as massage and exercises

are bringing improvement, no other treatment is required. If these fail one should proceed as above. Massage, etc., have often been carried on far too long. A month's trial should be ample to show if any good is likely to result. If not, other measures should be taken, or the patient sent to some occupation, according as to whether he has a useful working arm or not.

Excision or Arthroplasty.—The false joints obtained by either of these procedures are not particularly useful, the value of the limb being at best no better in most cases than if there is fixation in the best position in the case of the shoulder-joint, and they are therefore not recommended.

Cases with Loss of Bone and Want of Contact between Humerus and Scapula.—These patients have usually sustained a shattering wound of the head of the humerus, followed at the front by an excision of the head and the upper extremity of the shaft of the humerus. While this operation is justified as a life-saving measure, it is not advisable on any other grounds, as the functional results, as seen in orthopædic centres, are very bad. The arm hangs by the side, with the shoulder joint practically useless and the deltoid muscle stretched and mechanically out of action, except for a few degrees of abduction from the vertical. The arm should be placed on the shoulder splint described, with the upper end of the shaft of the humerus pushed into the socket, so as to relax the deltoid as much as possible, and allow of its recovering its tone. Massage and faradism should be applied to the muscle, either on the splint, or with

the arm kept at or above the horizontal. **Never for a moment** must it be allowed to fall to the side. It is very difficult to maintain the humerus and scapula in good apposition, and the position must be constantly watched and corrected. Plaster of Paris may be needed, and is certainly the most reliable method in difficult cases.

After three months of this treatment, the function of the joint may be tested, and improvement in abduction is to be expected. If the patient then has a reasonably useful shoulder with abduction half-way or more towards the horizontal, he may be discharged to some occupation, with instructions to wear the splint when his occupation allows it. On the other hand, the treatment indicated may not have done much good, there may have been a relapse after discharge, or there may be special reasons in the patient's case for the need of a more useful shoulder-joint. In any of these circumstances an operation should be performed to fix the joint in a good position, as this is the best that can be hoped for.

Operation for Fixation of Loose Shoulder-Joint.—This is done on very much the same lines as an arthrodesis after fibrous ankylosis. The head of the humerus being absent, the end of the shaft and the upper end of its outer aspect are freshened and fixed to the acromion and glenoid processes, freshened in the same way. The after-treatment is also much the same. The splint is kept on in 70° abduction from the scapula until union is firm and then let down gradually.

Fractures of the Humerus.

Mal-united Fracture.—Apart from involvement of joints, mal-union of fractures of the humerus have given little difficulty. They should be treated on general lines. If union is weak as shown by pain and tenderness on pressure or manipulation, the alignment may be restored under anæsthetic without incision. In the case of old compound fractures if the union is firm, and bad alignment interferes with function, the bone should be exposed near the site of union and correction made by osteotomy and plating or bone-grafting. Since the humerus is somewhat difficult to immobilise completely by splints, the situation is not ideal for bone grafting and the author has a preference for the Lane plate. If a simple fracture is being dealt with, the correction may be made at the actual site of the old fracture. The relations of the musculo-spiral nerve must always be borne in mind.

Ununited Fracture.—Whether there is loss of bone substance or not, the ends should be brought into apposition. Shortening is of no functional importance in the humerus. X-ray pictures are of great value here. If they show well-shaped ends which can be brought together by manipulation, a reasonable trial of hammering the ends, damming and injection of iodine should be made (see p. 31), but if, as often happens in war injuries, there are two sharply pointed fragments with the points just overlapping, the prospects of success of this method

are small, and open operation should be undertaken, and the broken ends fixed with plate and screws.

FIG. 7.—THE SCUDDER PAD.

The operation must be deferred until all inflammation has subsided and the wounds have been healed for

six months. Then a course of deep massage should be used as a test. Any inflammatory reaction is a certain indication that operation is still premature and further delay is necessary. At the time of operation the exposure of the bone must be so arranged as to avoid injury of the musculo-spiral nerve. In addition, it is important that the plates for fixation should not encroach on the musculo-spiral area or paralysis may result. For this reason long plates are unsuitable, and as firm fixation is a prime necessity, the use of two short plates is recommended. As the length of the bone is unimportant, enough bone may be removed to obtain good surfaces for approximation. To ensure an absence of improper rotation of one fragment on the other, it should be ascertained that the palm of the hand points straight outwards in pronation with inversion of the shoulder-joint, and straight forwards in supination with eversion.

A very satisfactory splint for fractures of the shaft of the humerus is the Scudder Pad (Fig. 7, p. 49). It should be made small enough to fit into the triangle formed by the arm, the forearm, and the side of the trunk. It is held in position by strapping over the opposite shoulder, and the wrist is supported by a sling, while fixation is secured by strapping round the arm and trunk.

Injuries of the Elbow-Joint may be divided into—

(*a*) Those with movement absent or restricted.

(*b*) Those with excessive movement (flail joints).

Cases with Limitation of Joint Movement.—These form a large and important class of war injuries,

and vary in degree from slight restriction of movement to complete ankylosis. Radiograms should always be taken, and any case without full ankylosis started on massage, etc., with the usual precautions as to sepsis.

There is sometimes a remarkable discrepancy between radiographic and clinical findings. Joints which look hopeless from X-rays may develop a surprising range of movement : others which appear nearly normal by X-rays are very disappointing in the results of treatment.

The Ideal Position.—There is difficulty in laying down a rule as to the best position for ankylosis of the elbow, as much depends on the avocation of the patient. Apart from this factor, a position just beyond a right angle is most generally useful, as the patient can then get a spoon or fork to his mouth and still have a fairly effective reach.

Bony Ankylosis.—While in the case of the shoulder joint, operations to give mobility to the joint are not attractive from the point of view of subsequent function, the reverse obtains in the case of the elbow, as useful joints with fair, or possibly full, degree of movement may be obtained by excision or arthroplasty. The problem of ankylosis has, therefore, to be viewed from a different standpoint. If the joint is already fixed in a good position the patient must himself decide whether it will suit his work better to have a thoroughly strong fixed joint or one possibly not allowing quite such strong muscular movements of the limb, but with an increased or perfect range

of movement of the joint. If the ankylosis is in a bad position an operation will be advised in any case, and the patient's occupation must again be considered.

Fibrous Ankylosis.—The joint is usually stiff in a too much extended position. Since it is impossible to be sure from X-ray or clinical evidence exactly how much mobility may be obtained by manipulation, this should be tried under full ether anæsthesia, as described below. If the joint fails to yield, the further treatment is as for bony ankylosis.

Extra-articular Lesions.—X-rays may show an entirely normal joint as compared with that of the opposite side. Furthermore, the position of scars may suggest that the obstruction is extrinsic. The treatment is practically the same as in the last case, but as the restricting elements are outside the joint, the prospects of obtaining mobility are brighter.

Limited Movement.—If healing of wounds is complete, massage and exercises should be started, and proceed so long as they are bringing improvement. When progress comes to a standstill, the result should be considered. If there is half range of flexion and extension the result may be put down as a good one, and apart from any obvious cause of further restriction, such as bony block, the patient may be discharged to his occupation. Any result short of this should lead to manipulative treatment.

Manipulation.—The chief dangers are—

(*a*) The lighting up of old suppuration.

(*b*) Fracture of the bones adjacent to the joint.

The former may be minimised by avoidance of

such treatment until suppuration has thoroughly settled down and wounds are soundly healed, the latter by the application of gutter splints lightly fixed to the arm and forearm and extending to the elbow joint. The use of splints is specially indicated in cases of great stiffness, or in those where there has been a fracture previously.

With the patient lying on his back under full ether anæsthesia, the back of the arm is laid upon a firm sandbag to support the humerus and limit the danger of its fracture. In the case of the right arm, the surgeon stands on the right side of the patient and grips the patient's forearm below the elbow with his right hand, and just below the middle of the forearm with his left. He then leans the weight of his trunk steadily against the back of the patient's forearm, and waits for the stiff joint to yield in flexion. Jerky movements and the use of muscular power are to be avoided. Experience and judgment alone can tell how much force may thus be applied safely, but by this method risks of fracture are reduced to a minimum. If the joint yields easily full flexion may at once be obtained. The joint is then fixed in this position by bands of strapping embracing the arm and forearm and by a sling from the neck to the wrist. This position is maintained for from one to three weeks, according to the amount of inflammatory reaction. The wrist is then dropped through a few degrees and slung so as to allow a small range of movement from full flexion. If the patient can use this range actively after three or four days, the sling may be

further loosened, so proceeding to a full range of movement, but increasing stiffness or pain about the elbow with spasm of the biceps are signs of inflammatory reaction being still present, and the process should be retarded, rest in full flexion being repeated, until these signs are absent. The disregarding of

FIG. 8.—THE TURNER SPLINT.

these signs is one of the commonest causes of failure of manipulation.

The joint may yield with difficulty and only through part of its range with the use of legitimate force. In this case one should be content with a partial gain and proceed as above. If there is thus a

useful gain of active movement, manipulation may be repeated when the joint has settled down. The danger of fracture of the olecranon must always be borne in mind.

Turner's Splint. — As an alternative to sudden stretching, this splint (Fig. 8, p. 54), may be employed, especially in cases in which manipulation is not expected to have the best results. It is incorporated in two plaster-of-Paris applications, one extending from the elbow to the axilla, and the other from the elbow to the dorsiflexed wrist. These bearings are necessary to prevent slipping. There is a screw adjustment opposite the elbow-joint, whereby the latter may be gradually flexed or extended by small daily changes of position. It is particularly useful in the middle ranges of movement, and also to gain full extension, for which purpose manipulation is not well suited. It is safer to use this splint in all cases of doubt, or when there seems a danger that manipulation may impair the prospects of mobility.

Bony Block.—Sometimes there is a definite bony resistance to flexion, and X-rays will show a mass of bone lying in or near the coronoid fossa. This condition should be excluded before manipulation is used. The author has approached these from the inner side, stripping the brachialis anticus from the humerus and removing the offending mass with mallet and chisel. It is a good plan to take a piece of the deep fascia from the front of the thigh and lay it against the remaining rough surface of bone before

replacing the muscle and closing the wound. The joint should then be put up in full flexion, following treatment being as after manipulation. The results are usually very good.

Contracted Scars.—One frequently sees at the bend of the elbow a contracted skin scar causing a serious interference with extension. It may be possible to straighten the arm passively on examination, or with greater force under anæsthetic. In either case there will be a recurrence of the flexion if a retaining splint is left off in a short time. In more severe cases the contracted band is so dense that straightening of the limb is impossible without tearing of the scar. There are two satisfactory methods of dealing with these cases, the choice depending on the temperament of the surgeon and the mental attitude of the patient. The more rapid cure is usually by operation, but methods of cure by splinting may be undertaken with good results. If the scar is stretched gradually and kept at full stretch long enough it will draw upon surrounding skin, and lose most of its tendency to affect the joint movements. A scar does not go on contracting for ever, and if there is adaptation of surrounding parts it becomes innocuous. In carrying out this method, therefore, the elbow must be fully extended and kept so for three months without intermission. If the scar is too severe for full extension at once, it may be gradually stretched by the use of the Turner splint referred to above. When this has done its work, a gutter splint may be applied to the back of the arm and forearm. At the end of

three months the splint may be left off intermittently, with the expectation of a good result. Any recurrence of flexion is a sign that contraction of the scar is still going on and that longer splinting is necessary.

In many cases a free excision may be thought more satisfactory. The scar is cut out and the elbow extended fully to show the whole area of the raw surface. A simple operation will often complete the cure. A pedicled sliding flap is made on one side or the other and brought over the raw surface and sutured. The flap may be cut obliquely with its base above the raw area and its free end towards the extensor aspect of the limb. The new raw surface from which the flap has been taken can be closed by drawing together the edges without prejudice to the future movements of the limb.

In cases of more severe scars it is a better method to borrow a portion of the skin of the abdominal wall.

The elbow is brought to the abdomen in what will subsequently be a comfortable position, and a generous flap of suitable shape is turned up including the skin, fat and superficial fascia of the abdomen. This is laid over the raw surface of the arm and sewn neatly as far round its edges as possible. The pedicle remaining attached to the abdomen should be of the whole width of the flap. It is well to turn the forearm up and suture temporarily the lower edge of the abdominal wound to the inner edge of the elbow wound as far as possible, so as to reduce the raw surface on the abdomen and to render the condition

cleaner for the second stage. This consists of division of the pedicled base of the abdominal flap and of the temporary suture line below, followed by completing the closure of the respective wounds now separated. This second stage should be begun in three or four weeks, and to be sure of proper return of blood supply it is safer to divide a portion of the pedicle at a time, and then wait for a week before completing the separation, or a little may be cut every two or three days after the first three weeks with local ethyl chloride anæsthesia. When separation is complete and the raw surfaces are closed, the arm should be splinted in the fully extended position for a fortnight to allow the wound to heal, after which active movements may be allowed. There is no reason to expect much tendency to recontraction as there should be primary union between the open raw surface and the borrowed flap. The results of this operation are most satisfying and far superior to those after skin grafting.

Open Operations to Mobilise the Elbow-Joint.—These may have to be considered after the possibilities of the above-mentioned procedures are exhausted. The case must be put before the patient in the light of his future occupation. A reasonably strong joint with probably largely increased utility can be depended on. The choice then lies between arthroplasty and excision. One can expect from arthroplasty a joint without lateral mobility, and at least half range of both flexion and extension. With excision the chances of complete flexion and extension are better and also those of full pronation and supina-

tion, but there will certainly be a little lateral play. This may not be of real importance, and a man with an excised elbow is sometimes fit for the hardest work. Moreover, a remedy for undue mobility may be found if necessary in a simple operation later to form new lateral ligaments for the joint from strips of fascia lata taken from the thigh.

Excision.—This differs from similar operations for tubercle in that one usually has a free choice as to the amount of bone to be removed. The posterior incision is convenient. The bone removed should just include: (*a*) **above,** the tips of the epicondyles; (*b*) **below,** the articular surfaces which enter into the elbow-joint itself. The limb should be put on a posterior gutter splint extending from the axilla to the finger tips, in full supination with as much extension on the elbow as possible. At the end of a week the splint is removed and the joint put up in full flexion and supination, with a wrist-to-neck sling and a bandage round arm and forearm. The sling should be slackened gradually so far as good active power is maintained. Massage and faradism are begun early, and active movements encouraged within the limits of the sling. The results are usually excellent.

Arthroplasty.—The joint is exposed as in excision. All adhesions must be broken down thoroughly and the joint surfaces levered apart. The superior radio-ulnar joint, if affected, must be similarly treated. In this operation, as in the preceding, the anconeus and the aponeurotic extension of the triceps on to

the forearm must be carefully preserved in continuity. The roughened joint surfaces must be smoothed with a chisel and the tip of the olecranon removed. A flap of aponeurotic deep fascia, four inches by eight inches, is then taken from the previously

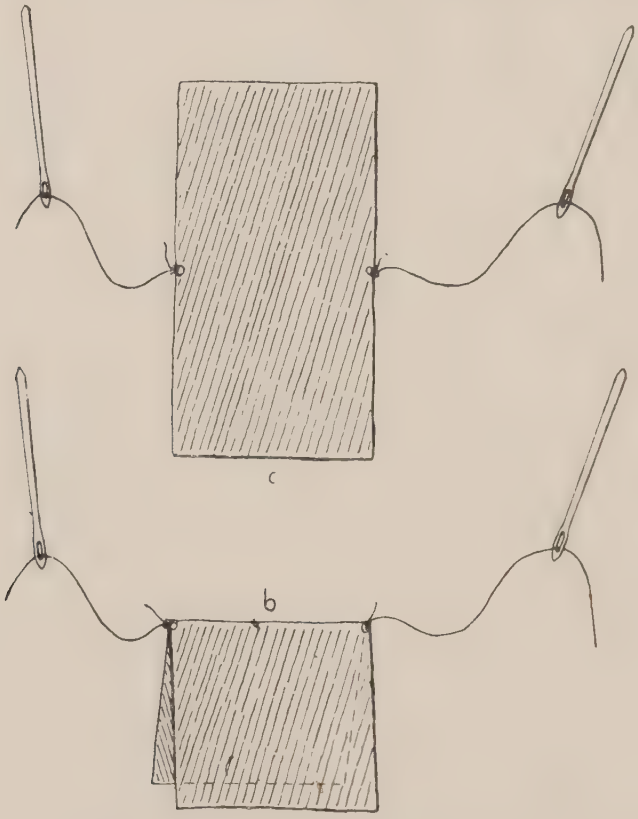

FIG. 9.—FLAP OF FASCIA LATA.

prepared antero-external surface of the thigh. While it is still lying on its muscular bed, a length of catgut about eight inches is fixed to the middle of each of the long sides of the flap. A long straight-cutting needle is threaded on each piece of catgut and the flap is

lifted by them. It then hangs in a double curtain, four inches square (Figs. 9A and 9B). The needles are then passed into the elbow wound well to the respective sides and out through the skin at the front of the joint. By pulling on the sutures the flap is carried well home into its position. The two ends are tied across the skin of the front of the joint. The double flap is then arranged smoothly over the whole of the raw surfaces of the joint, a portion being pushed down into the superior radio-ulnar joint. The triceps and its extension are sewn with a continuous fine catgut, the skin wound is closed, and the joint put up in full flexion and supination. It is kept in this position for a fortnight and then let down gradually, active movements being encouraged within the range of the sling. Massage and faradism should be begun early, but passive movements should not be ordered. The surgeon may himself employ gentle stretching in one direction, aided by active efforts by the patient. To and fro movements are to be condemned in this case, as in all. There is no fear of stiffness in a too much flexed position. Supination should be encouraged and maintained, if necessary, at the expense of pronation.

Elbow-Joints with Excessive Movements (Flail Joints).—A number of cases reach the orthopædic centres after having had a wide excision of the elbow-joint, presumably as a life-saving measure. The operation should never be undertaken lightly, as the functional results are very bad. Without most careful after-treatment, and perhaps in spite of it,

the ligaments and muscles become stretched and weak and the forearm hangs by the side as a useless appendage.

The wrist should be slung to the neck, and a figure-of-eight bandage placed over the elbow to draw together the slack joint. Massage and faradism are

FIG. 10.—HINGED ELBOW SPLINT.

to be used daily, the bandage being temporarily removed, but not the sling. The patient should be encouraged to stimulate the weak muscles by attempting flexion movements. Some cases improve a great deal and may be discharged with instructions to wear the sling when the limb is not in active use.

Others with less or no improvement are fitted with a hinged poroplastic arm-splint (Fig. 10, p. 62), having a block to prevent extension beyond a right angle. They can then be discharged to employment, functionally as well off as with an ankylosed joint and with possibility of gradual movement. If, however, the stiff joint is preferred it can be obtained by freshening the ends of the bones and fixing them with screws or nails at 100°, or in a position selected by the patient.

Mal-united Fracture of the Forearm.—As a rule these have to be regarded from the point of view of function only. In cases with tender and therefore unsound union rectification can be obtained by manipulation under anæsthetic. Double fractures with cross union are troublesome, but operation should be performed. The site of the fracture is exposed and often a large mass of intervening bone is found. This must be removed by chisel and mallet, and a plug of fascia from the thigh placed between and round the raw bone surfaces. The limb is splinted in supination and left for a fortnight before massage, passive movements, and exercises are begun.

Ununited Fracture of Forearm.—The usual type of case is one in which one bone is intact or united and the other is ununited with a gap of an inch or more. At a suitable time (see Introduction) bone-grafting should be performed. If Albee's method is used a graft should be taken from another bone, as a local sliding inlay graft involves the opening up of too much tissue in a part formerly septic. The

bone-splitting method is very suitable and need not be combined with a plate. It is important that the graft be fixed with the forearm fully supinated, and this position must be preserved until union is sound.

Non-union of the ulna combined with dislocation of the head of the radius is not infrequently seen. In this case the upper end of the radius must be

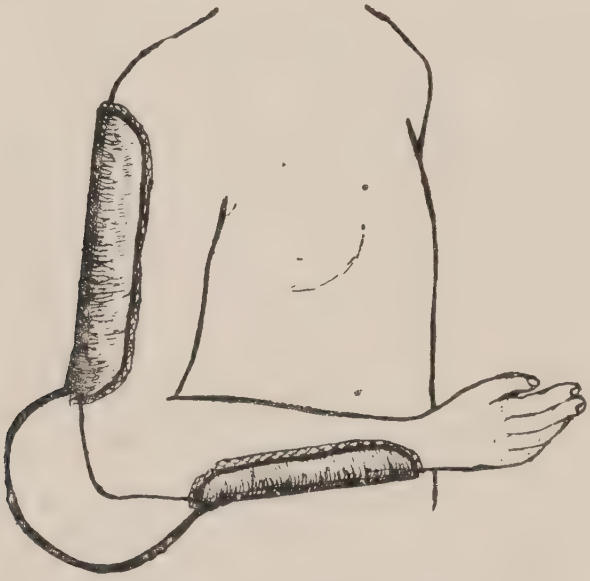

FIG. 11.—GUTTER ELBOW SPLINT.

removed, and the piece taken out may be used for the ulnar graft. If, however, the gap in the ulna is small, one may consider removing rather more of the radius and bringing the ulnar fragments end to end. In either case, after the forearm is splinted in supination, the limb should be put up with the elbow flexed as much as is possible, that the upper end of the radial fragment may be kept in relation with the capitellum.

Pronation and Supination.—These movements are

often lost or limited. Since for practical purposes the radio-ulnar joint extends from the elbow to the wrist, it is the largest movable joint in the body and liable to injury in any of its parts. In this joint, as in all others, there is a tendency, in fatigue or injury, to the assumption of the position of rest, in this case pronation. For this reason it is of great importance that all efforts of treatment should tend in the opposite direction, towards supination. Apart, therefore, from certain cases of fracture, *e. g.* Colles's, where pronation is necessary, for alignment purposes, the forearm should be fixed in the supinated position. In cases of limited movement, exercises of supination should be ordered, and if these are unsuccessful, manipulation into this position should be performed either alone or in association with corrections of the elbow or wrist. If the movements are to be lost altogether something short of full supination is perhaps to be preferred as the final position, but the natural tendency to pronation will be enough to ensure this in cases of fibrous ankylosis, in spite of all efforts of the surgeon towards supination, since splinting is not very easy and constant supervision and reapplication are often necessary. The most certain method is by plaster of Paris, including the lower part of the arm, the whole forearm, and the palm of the hand. In less difficult cases a metal splint is to be preferred (Fig. 11, p. 64). The forearm gutter is twisted in the direction of supination, and an anterior splint similarly twisted is also applied extending from the elbow well on to the palm. In other instances, Morton's

Supination Splint (Fig. 12) will suffice. Where bony ankylosis of either radio-ulnar joint is certain or probable, the degree of pronation, or supination, must be adapted to the patient's future needs.

Wrist-Joint.—The treatment of gunshot injuries of the wrist or involving the wrist and causing stiffness,

FIG. 12.—MORTON'S SUPINATION WRIST SPLINT.

can almost be summed up in one word—Dorsiflexion. If this position is fully reached and maintained by splinting, other movements can take care of themselves. Even if ankylosis occurs the resulting disability is comparatively slight. The hand is in the position of activity, the flexors can act well, and there is no

tension on the extensors. This point cannot be emphasised too much. One often sees ugly flexed stiff wrists, whose appearance and function can be very greatly improved by dorsiflexion. Quite frequently cases are seen in which it is said that dorsiflexion has been attempted without success. This may mean that the surgeon has backed the power of his own wrist against the stiffness of the patient's wrist and

FIG. 13.—WRENCHING FLEXED WRIST.

the resistance of his flexors. It should be understood that very strong application of force may, and often must, be used to obtain the desired end. In all difficult cases ether anæsthesia should be employed, and the wrist bent back with the aid of the Thomas Wrench (Fig. 13). If the patient's lower forearm is steadied by the surgeon's grasp there is no danger of fracture. In cases of bony ankylosis a linear

or wedge-shaped osteotomy must first be performed. The normal wrist can be extended to a right angle, and this should be the objective in dorsiflexion, as some of the correction will probably be lost in spite of careful after-treatment.

In difficult cases, a plaster-of-Paris splint should be applied from the heads of the metacarpals nearly to the elbow. It is sometimes helpful to embody a Short Wrist Splint (Fig. 14) in the plaster, or in

Fig. 14.—Short Wrist Splint.

milder cases this splint may be used alone. In the latter case the splint may be removed for massage and active movements at the end of a week, and reapplied after treatment so long as any tendency to recurrence is seen. In the more severe cases, such as need plaster, this should be kept on for a month, after which it is replaced by a wrist splint, and massage started. It is better not to use any passive movements of flexion. If this movement is possible it

will come naturally in course of time. Supination must be maintained throughout.

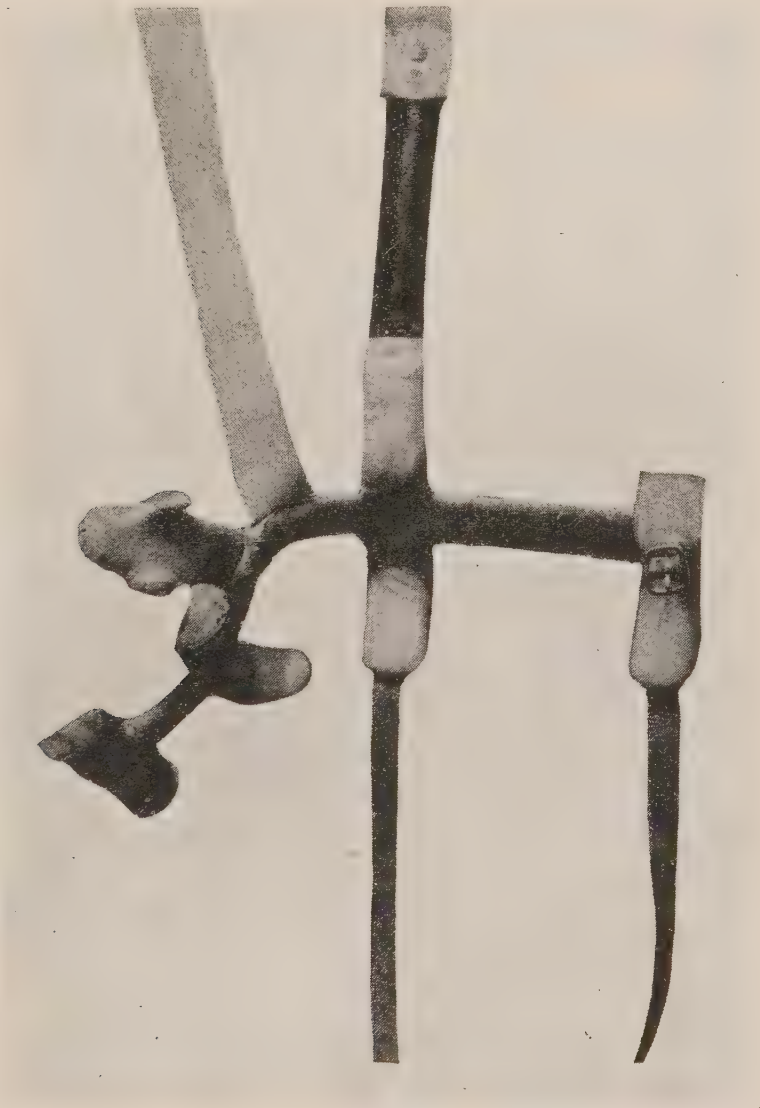

FIG. 15A.—LONG WRIST SPLINT.

Flail Wrist.—In these cases there is always a forward dislocation of the carpus and hand on the

forearm, with loss of the lower ends of the forearm bones or of wrist bones, and the muscles being all at a mechanical disadvantage the hand is practically useless. Operation is always needed. The joint is

FIG. 15B.—LONG WRIST SPLINT APPLIED.

to be exposed, the lower ends of the radius and ulna are freshened, and beds are scooped out for them in the carpus slightly towards its posterior aspect. Small skin incisions are made in the thenar and

hypothenar eminences, and nails are driven in engaging the lower ends of the radius and ulna respectively. Fixation should be made in good dorsiflexion, with supination and a Long Wrist Splint (Figs. 15A and B, pp. 69 and 70) applied and kept on until consolidation is complete. There may be some lighting up of old suppuration, but it need not interfere with the result. The nails should be buried in the palm and may be removed at a later date if necessary. The degree of recovery of function is necessarily uncertain, but no other procedure will give such a good chance.

Dislocations of Carpal Bones.—Sometimes X-rays will show the dislocation of an individual carpal bone interfering mechanically with flexion or extension. The bone should be removed by operation and the wrist put up in dorsiflexion. Active movements may be begun when the wound is healed.

Traumatic Contractures.—These occur very commonly in association with gunshot injuries of the upper limb; and vary in degree from those of the so-called Volkmann type, with joints free, but with shortened muscles, to others with stiffness of many joints and hardening and contraction of nearly every muscle of the forearm and hand. The exact pathology is often obscure, but there may be lesions of nerves or blood vessels, old compound fractures, hæmorrhages and fibrosis of muscles or a preceding widespread suppuration and plastic infiltration of subcutaneous tissues and tendon sheaths, or all these may be combined. Everything possible should be done from the first to improve the circulation by Massage,

Contrast and other Baths, Faradism, etc. The type of traumatic contracture, sometimes called Volkman's Ischæmic Paralysis, requires special discussion. The attitude is characteristic. The interphalangeal joints are held flexed and the metacarpo-phalangeal joints hyper-extended. When the wrist is passively flexed the fingers are passively extended by relaxa-

Fig. 16.—Splint for Traumatic Contracture.

tion of the tension of the flexors, and increase of that of the extensors. The condition is due to a fibrosis of the muscles of the forearm from pressure of hæmorrhages, scar formation, or fracture, sometimes aided by injudiciously tight bandaging. There is usually no affection of nerves with either sensory or motor palsy, but the fibrotic changes adversely affect the circula-

tion, and the fingers may be blue, cold, and shrivelled. Operations of bone-shortening and tendon-lengthening have been done with satisfactory results as regards the contracture, but they have small effect on the circulation. Treatment by gradual stretching of the shortened muscles has been attended with the best of results. The wrist is first flexed and the fingers are splinted in full extension. Separate gutter splints may be used for each finger, or a malleable splint with forearm hand and finger portions may be used from the first (Fig. 16, p. 72). In a day or two the metacarpo-phalangeal joints are splinted in extension, the wrist still being kept fully flexed.

With the hand and fingers thus kept in a straight position, gradual extension of the wrist is made from day to day, until all the joints are in a position of full extension. As the scarred muscles become stretched the pressure on blood vessels is released, and the circulation and nutrition of the hand and fingers improve correspondingly. Massage should be used as far as possible during the period of stretching. When this is completed, the splints may be removed daily for more thorough massage, contrast baths, etc., but the splinting should be relinquished only gradually and not omitted altogether for three months from its commencement. Simple cases of this kind do extremely well, but in the more complicated contractures where there are also nerve lesions, or where there has been widespread suppuration through the tissues, the outlook is less good. Apart from the special treatment of nerve lesions, the cases

are dealt with in much the same way as in the simple type—that is, by gradual unfolding by splints from below upward. The metacarpo-phalangeal joints should not be hyper-extended, as they tend to become stiff in that position. This condition of hyper-extension of the metacarpo-phalangeal joints is often present at the first in combination with flexion contraction of other joints of fingers and wrist. In this case flexion of the metacarpo-phalangeal joints

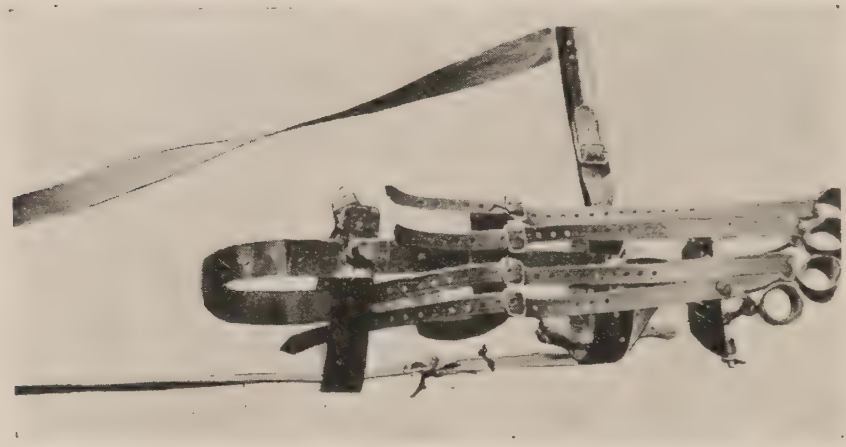

FIG. 17A.—MORTON'S FINGER FLEXION SPLINT.

must be begun as soon as the wrist has been brought into full extension. This is frequently a very difficult matter, as the stiffness is of an extreme degree. Manipulation under anæsthesia is of but little use, and the principle of gradual stretching is by far the most satisfactory. For this purpose Morton's Finger Flexion Splint is advised (Figs. 17A and B). This is a modification of the short wrist-splint, with special rings and traction straps arranged in such a way as

to exert a constant pull at right angles to the long axis of the proximal phalanx. This should be applied daily for as long as is tolerable, constantly if possible, until the metacarpo-phalangeal joints have been pulled down to a right-angled position. If stiffness of these joints can be overcome the main difficulty, in

FIG. 17B.—FINGER FLEXION SPLINT APPLIED.

getting full flexion of the fingers, has been met. Massage, paraffin baths, and faradism are all of value in increasing the suppleness of the fingers. A light wrist-splint should be used at a later stage, so long as there is any tendency to recurrence of loss of extension of the wrist.

The ultimate results of these more complicated

lesions, so far as they have gone, have often been extremely disappointing. The stiffness appears to be of the nature of a permanent fibrosis of woody hardness, and the question arises as to how long hospital treatment should be continued, and when the patient should be discharged to make the best of a bad business in the hope that time will do something to relieve the disability. It is recommended that treatment should continue as long as there is any improvement, and that when this comes to a stop, and there is no change during three months, he should be discharged to civil life, **provided all corrections have been conscientiously made,** and all lesions of nerves and tendons dealt with and their further treatment provided for.

Injuries of the Hand.—The preceding paragraph refers to involvement of the hand in lesions chiefly of the forearm. Injuries below the wrist lead as a rule to disability of a part of the hand rather than the whole.

Wounds of the Metacarpus.—These include injuries of any or all structures of the part. When tendons are involved, the site should be exposed by raising a flap, the tendons freed and wrapped in a portion of fatty tissue or of fascia from the thigh. Where continuity cannot be established suitable neighbouring tendons may be used, their central portion being inserted into the sound part of the damaged tendon beyond the lesion. In all these cases it is well to lay a flap of fascia between the tendons and the overlying scarred integument, to prevent adhesion. If no

reconstructive operation is feasible the fingers should be allowed to be semiflexed, so that they may be of some use in co-operation with an uninjured thumb.

Injuries of the Thumb.—The greatest conservatism should be employed here. The thumb is often distorted as a result of injuries of its base. In such cases an excision of the affected joint is to be made and the digit placed in such a position that the unaffected little finger can be opposed to it. Such a procedure brings about a very great gain of utility even if the thumb is stiff.

Injuries of the Fingers.—Where there is involvement of the tendons and joints of one or two fingers, such as may occur after gunshot injuries, it is not profitable to waste too much time in unpromising attempts to restore function. Unless the fingers can be made useful, it is far better to proceed to amputation at an appropriate joint than to allow one or two useless digits to interfere with the function of the rest. This applies also where joints only are involved, but where tendons alone are affected a restorative operation should always be considered. Much sound judgment is required. A joint with complete ankylosis, either bony or fibrous, will render any digit except the thumb perhaps worse than useless, and so call for amputation. If, however, there is a small range of movement, and no great deformity, one might well wait during a period of six months of suitable occupation to see if progress is then enough to warrant a further trial. Nature will sometimes succeed where the best efforts of the surgeon have failed.

INJURIES OF THE TRUNK

From the orthopædic standpoint, injuries of the trunk are mainly important in their effects (*a*) on the alignment and stability of the Spinal Column, and (*b*) on the functions of the Spinal Cord.

It is proposed to discuss here only a few types that are common, rather than to attempt a survey, however brief, of the whole subject.

Scoliosis.—Quite a number of cases are seen with this deformity, and a history of its onset, after an injury received on active service.

There is frequently the scar of a wound of the lumbar or abdominal muscles on one side or the other. Presumably the pain of the contraction of the wound in healing has led to a partly unconscious bending towards the affected side, and the attitude assumed has become habitual. There is always a large functional element in these cases, and reference will be made to them in discussing functional deformities.

Massage and faradism are of value, but it should be seen that these are properly applied, namely, to the muscles of the convex side only, and not, as sometimes is done, to the hollow side in an attempt to develop the muscles to fill up the hollow. Treatment of the latter kind will obviously tend to maintain and increase the deformity. Active exercises are very

good, especially the Klapp crawling exercises. There is often some adduction spasm of one hip joint, usually on the side of the concavity of the spinal curve. This results in a remarkable apparent shortening of the lower limb on this side. There is a temptation to prescribe a raised boot on this side, but the principle is absolutely wrong, as this tends to perpetuate the deformity. The boot of the apparently lengthened limb must be raised as far as is practicable, so as to tend to throw the patient over on the concave side unless he straightens his spine. In other words the tilted pelvis must be brought level. The knee is usually held flexed on the side of apparent lengthening. In this case a back splint may be applied to the knee with good effect. Abduction of the adducted limb on a Thomas Double abduction frame for a few weeks, has sometimes proved beneficial. In resistant cases where the deformity appears to be a fixed one, treatment by plaster after Abbott's method may be necessary. A plain gaspipe frame, five feet by three, supported on two tables, makes a fairly efficient substitute for the orthodox Abbott's frame. Some special knowledge of this subject is desirable, and in no circumstances should be a plaster jacket be applied without simultaneous correction of the deformity.

Angular Kyphosis.—This is invariably due to a crushing together of the bodies of a small number of vertebræ, either by an injury causing fracture with subsequent bowing, or by the superincumbent weight of the head and trunk, bearing on the site of a local disease of the bodies, this disease being nearly always tuberculosis.

It is rare to find this deformity as the result of a local gunshot wound, possibly because the wound calls attention to the local conditions, but it is usually preceded by a shell explosion in which the patient has been thrown down violently or partially buried. The rapidity of onset of the deformity, after such an accident, will sometimes help to distinguish the case as one of fracture; but in many cases it is by no means easy to diagnose this condition from one of caries, as the history, both as to the degree of violence and the time of onset of the deformity, may be very vague. A good skiagram may be helpful in showing displaced fragments of bone indicating fracture, or thinning of the intervertebral discs and a destructive process in one or more bodies suggesting tuberculosis.

In either case, if there is an angular kyphosis, with muscle spasm on passive movement in all directions, in addition to the general signs of local pain and tenderness and the absence of compensatory curves, it is evident that rest is required; and the patient must be laid either on a Thomas Spinal Frame with headpiece, or on a Bradford Frame bent upwards (Fig. 18, p. 81).

Whichever of these appliances is used, it is important that the spinal prominence should be firmly supported, the support being augmented from time to time, so as to tend towards hyper-extension at the site of the lesion. By this means there is a gradual reduction of the posterior bowing. Mere rest on a soft and yielding bed is likely to lead to an increase of the deformity.

As regards the duration of treatment, this depends on the nature of the pathological process. Any lesion of this type which is not consolidated after three months of recumbency must be regarded as tuberculous and treated as such. Any full discussion of the treatment of spinal caries is out of place here, but it may be well to refer to the operation of spinal fixation as an alternative to prolonged rest as being eminently suited to cases of this type.

FIG. 18.—BRADFORD FRAME.

The method of lateral grafts as a modification of Albee's original operation is simple, and gives good results. A flap of good size is turned to one side, the muscles are separated on each side from the groove between the posterior spinous and articular processes, and the floor of the groove roughened by chipping with a chisel. A strip of bone, including periosteum and medullary tissue, is taken from the subcutaneous surface of the tibia: this is split longitudinally and the two strips thus formed are laid in the prepared groove on each side of the spinous processes. When

they are placed, the groups of muscles of the two sides are sewn together across the middle line, with a continuous stout catgut suture, and the skin wound then closed. The grafts should be long enough to extend over two vertebræ above and below the site of the lesion. The patient lies on his face throughout the operation, the knee being flexed when the tibial graft is being obtained. Before the grafts are placed in their beds, it is well by gentle pressure to reduce slightly the posterior bowing. Sandbags beneath the shoulders and pelvus will aid in this. Any rectification gained can be maintained if the site of the graft is well supported during after-treatment. An important advantage of this procedure is, that the graft will lie flatter in its bed and in better apposition with the vertebræ if any posterior bowing can be reduced.

Three months' rest must follow, on one of the frames mentioned, and after this the patient may get up and walk, first in a carefully moulded plaster jacket, and later in a poroplastic jacket reinforced with metal strips. In lumbar lesions the supporting jacket must reach to the base of the neck, embracing the pelvis below. If the lesion is dorsal or cervical, the jacket must extend to the chin and occiput.

Diffuse Kyphosis.—This is due to a Traumatic Spondylitis, or may follow septic processes elsewhere, and is similar in its progress to cases of osteo-arthritis or rheumatoid arthritis occurring without trauma and affecting many joints of the spine. The deformity is increased by the body weight and muscular contraction if the patient is allowed to walk, and by the

assumption of the position of rest in a soft bed with a pillow under the head and shoulders. The patient should be laid flat on his back on a hard mattress and without a pillow, as soon as this is practicable. When this is first tried it will probably be found that the stiffness of the spine will not allow the head or pelvis to reach the surface of the mattress. In this case they must be lightly supported, the support being gradually reduced as the spine falls back into the straight position. When this is reached a Bradford frame can be used. This is bent with a slight general convexity upwards, and the convexity is increased as the spine gradually becomes hyper-extended until a full correction is obtained. Some cases are very resistant to this line of treatment, and no progress towards reduction is brought about. In such instances a plaster-of-Paris jacket may be applied with the patient suspended by the chin and occiput, if possible, as in cases of spinal caries. The plaster should take its bearings from the pelvis below and from the shoulders above. A small posterior window is cut opposite the upper lumbar vertebræ, and a large window in front exposing as much as

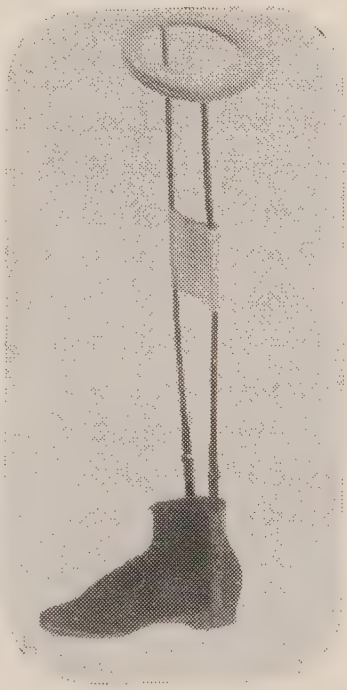

FIG. 19.—THOMAS CALIPER.

possible of the chest and abdomen. Progressively increased cotton-wool packing is then inserted into the posterior window, until the normal lumbar concavity is restored. Reapplication of jackets may be needed

FIG. 20.—WALKING CHAIR.

before correction can be completed. It should be remembered that, in a general kyphosis, the deformity consists chiefly in an obliteration of the normal posterior concavities of the lumbar and

cervical regions, and their replacement by convexities which follow the line of the normal dorsal convexity, itself perhaps only slightly exaggerated. No pronounced correction is expected, or indeed needed, in the dorsal region. If, then, the abnormal lumbar convexity can be converted into a concavity the whole aspect of the case is changed for the better, and the patient, instead of being able to look only towards the ground, can look straight ahead, and hold himself in an approximately erect attitude. The centre of gravity having thus been thrown backwards, the body weight will have very little tendency to reproduce or increase the deformity, The patient may then be allowed to walk in a reinforced poroplastic jacket embracing the pelvic and shoulder girdles. He should continue to sleep on the frame or on a hard mattress with a pillow under the loins and none under the head. Forcible correction is very rarely needed, and is accompanied by grave risks. It will, therefore, not be necessary to discuss the procedure here.

Paralysis of the Spinal Cord.—This may be referred to here more conveniently than in connection with injuries of Nerve Trunks. Operations on the spinal cord are very rarely indicated in the late stages. **In no case which survives the immediate injuries is it impossible to obtain locomotion.** This statement may not be universally true, but it is a good working basis of treatment. Massage and electrical treatment should be used from the first. The hips should be kept extended and slightly abducted, the knees straight

and the feet at right angles to the legs. Any departure from these positions must be corrected by splints, tenotomy, or manipulation. As soon as the condition of the spine allows it, walking splints should be supplied. A long Thomas Caliper Splint, with fixed ankle-joint (Fig. 19, p. 83), is necessary. With the needed appliances fitted, the patient should be encouraged to try to use his lower limbs in walking with helpers on either side or in a special Walking Chair (Fig. 20, p. 84). Even with complete paralysis of both lower limbs the patient wearing double capliers may learn to progress on his feet, aided by crutches or sticks, by means of twisting movements of the trunk to throw forward first one foot and then the other. The patient should never be allowed to think that his case is hopeless, and few are more grateful than those who, after being apparently helplessly bedridden, are by any means enabled to walk in any sort of fashion.

INJURIES OF THE LOWER LIMB

In discussing restoration of function in the lower limb, it must be emphasized that the problem is a different one from that which concerns the upper limb. Whereas in the case of the arm we have to provide for range of movement as well as strength, so that treatment is often in the nature of a compromise between the two, in the lower limb this is not so. All movements compatible with strength are to be sought with all our endeavours, but never at the expense of stability. The main object of treatment is, therefore, clear—to render the limb as capable as possible of supporting the weight of the body. Fortunately, if this result is good, the function of the limb as a whole is good, even with stiffness of hip, knee, or ankle joint.

The Hip-Joint.—Interference with function is nearly always in the direction of limitation of movement, in most cases due to a septic arthritis from a gunshot wound of or near the joint. If the position is good, exercises, of which the best is walking, may be begun; but if the attitude of fixation is a faulty one, it is well to proceed at once to correct this without regard to subsequent movements.

The Ideal Position.—In the normal person the most stable position in standing is one with slight abduction of both hips. This is one reason for aiming at

abduction in ankylosis. Again, a limb which is *ad*ducted is practically shorter than its fellow. Thirdly, there is often some real shortening in association with the joint lesion. For all these reasons the

FIG. 21.—ABDUCTION FRAME.

position of abduction is desirable and should always be obtained by one or more of the methods at our disposal. In addition the joint should be fully extended for obvious reasons as to length and to

avoid lordosis. On the question of Eversion or Inversion there is some difference of opinion. It is the usual practice in this country to aim at slight eversion. The slightly everted position is certainly the least unsightly.

Bony Ankylosis.—If the joint is in the position defined above, no further treatment is needed. If not, osteotomy is to be performed after all sepsis has cleared up for some months. The inter-trochanteric variety is generally the best. A vertical skin incision is made downward from the top of the trochanter, and its outer surface exposed, the periosteum being stripped forwards and backwards. A wedge of bone is removed of a size depending on the degree of adduction to be overcome. A width of an inch is usually needed. It should be wider at the back than at the front if flexion is also present, as is usual. It should extend in depth nearly but not quite through to the inner side of the bone. If the bone will not then yield the osteotome or chisel may be driven through the remaining bridge. A definite giving way is necessary to obtain the required result, and the wedge-shaped opening must be fully closed by approximation of the edges of the gap. Tenotomy of the adductors should be readily done if there is any difficulty. The wound is closed and the patient fixed in a Thomas Abduction Frame (Fig. 21, p. 88) for six weeks, when he may be allowed to walk, or he may be put into a well-moulded plaster spica, including the foot, and allowed to get about on crutches in three weeks. It is a good plan to keep the sole of the boot on

the sound side raised half an inch to aid abduction on the affected side.

Fibrous Ankylosis.—This term is, of course, used in a wide sense, since it must include cases in various stages leading up to the final condition. It is usually the result of a septic infection of the joint cavity, with the replacement of its articular cartilages by granulation tissue which in turn is transformed into fibrous tissue. The destruction of the cartilage may be only partial. For these reasons the process may be incomplete in regard to time or degree, or both, and it is often possible to correct a faulty position by manipulation or suitable splinting. Corrections by splints and extension are done in the same way as in tuberculosis of the joint, and do not need description here. The Thomas Abduction Frame already referred to is particularly suitable for this purpose. Manipulation will save time and may often succeed where the slower method fails. The patient lies on his back, anæsthetised with ether. An assistant steadies the pelvis, and lower limb of the opposite side. A perineal band may be applied on the sound side and fixed to the table near the shoulder of the sound side, or the patient may be already partly fixed on the abduction frame. One or more assistants may pull on the affected limb by a grip above the knee. Since steadiness of pressure or tension is of the greatest importance in all manipulations, it is better to have a task which is well within the combined strength of those assisting rather than to rely on a great effort of muscular exertion. While extension is thus being applied by

assistants, the surgeon gradually abducts the limb, at the same time guiding, as it were, the pull of the assistants into a direction of greater abduction. Tenotomy of the adductors close to the pelvis is of great help and should always be done in cases of long duration. The desired result is often obtained much more easily than this description may suggest, and one assistant may suffice. It is important to remember to obtain full extension, for which it may be necessary to turn the patient on to one side. Rotation must also be corrected. This may be very difficult, but the operator must persevere even at the risk of fracture. The occurrence of fracture may indeed be of help in bringing the limb into the desired position, and may sometimes obviate the necessity for osteotomy.

False Ankylosis.—Radiograms should be taken in every case where the diagnosis is doubtful. The appearance in bony ankylosis is, of course, one needing no description. In fibrous ankylosis and conditions leading up to it the changes seen by X-ray may be slight. Radiograms of the sound hip for comparison are essential. There may be clear signs of arthritis, in haziness or irregularity of outline of the elements of the joint, or there may be only very slight narrowing of the space seen between cup and ball. Even this may not be distinguishable, and yet the joint may be very stiff in the usual "position of rest," that is, in adduction and flexion, which will always be the case where a joint has been allowed to become stiff without measures to counteract its attitude. Whether a movable joint is to result or not, the essential thing is

to obtain the "position of activity" in this instance as in all others. This corresponds to the ideal position of ankylosis, namely, Abduction and Extension. The method of procedure is, therefore, the same as in the case of fibrous ankylosis, and the actual diagnosis of intrinsic or extrinsic adhesions is of secondary importance. The correct attitude having been obtained, the degree of freedom of movement may be noted. If the joint moves quite freely, and without creaking, one may conclude that the obstruction to movement was entirely extra-articular. In such case prolonged rest is not advisable. Massage and active movements may be started forthwith. On the other hand, if correction is difficult, and there is grating, the limb should be rested as in above-mentioned conditions. If the final result is to be a stiff joint, a good position is thus assured. If any small or greater degree of movement is possible in the future, it can be allowed to return slowly and its prospects are improved by rest until all inflammatory reaction has subsided.

Limited Movements.—X-rays will give evidence for or against involvement of the joint surfaces. Limitation of all movements of the joint indicates a condition of arthritis. In the absence of pain, the inflammation may be regarded as having subsided. If the ideal position is included in the range of movements the patient may be allowed to walk and return to his occupation. Should abduction or extension be lacking these should be obtained by exercises or manipulation and raising the sole of the opposite boot. After a period of rest, walking may be allowed and the patient

discharged. On the other hand, if any one movement of the joint is quite free throughout, it is a sign that the obstruction is probably outside the joint. In the absence of X-ray or other evidence that the obstruction is bony, massage and exercises to increase the limited movements should be used. The test of rotation is particularly valuable. If its range is complete there is good reason to think that the whole of the joint movements may be regained. Should exercise, etc., fail to bring about the required result, the joint should be manipulated under ether and put once, and once only, completely through each movement. This should be followed the next day by massage and active exercises. Passive movements should be firmly restricted to steady pulling or pushing in one direction. To and fro passive movements are worse than useless. If they are painless, they are not needed : if they are painful, they are increasing the inflammatory reaction.

Bony Block.—Radiograms will sometimes show the presence of a mass of bone above the neck of the femur, due to fracture, callus, or an osteophytic deposit on the lip of the acetabulum or the neck of the femur. Abduction will be limited. An effort may be made to displace this by full abduction of the femur, with or without tenotomy of the adductors. If this fails, the mass should be loosened with a chisel or removed. When full abduction is reached, it is maintained with the abduction frame or a plaster spica bandage for a month, after which active movements may be begun.

Ankylosis of Both Hip-Joints.—In the event of this

very crippling condition, the aim must be to obtain a joint with at least some degree of movement on one side and a strong joint in good position on the other. In a general way the joint which is less disorganised will be chosen for operation. Other things being equal, however, the joint in the worse attitude should be selected.

Operations for removing Ankylosis.—A long external incision is made from the iliac crest to the bottom of the great trochanter. The gluteus maximus is divided low down and reflected upwards. The edges of the gluteus medius and minimus are defined down to their insertions into the trochanter. The trochanter is then sawn or chiselled off and turned upwards with the two lesser glutei. The outer aspect of the hip-joint is then exposed. If there is a reasonably good preservation of bony elements of the joint, the head of the femur is separated from the acetabulum, the head and cavity smoothed with chisel or gouge, and a large flap of fascia lata placed in the acetabular cavity. The head is then replaced with the flap of fascia interposed between the bony surfaces. The trochanter is replaced and fixed with nails or screws, the gluteus maximus sutured and the wound closed.

The patient is placed on the abduction frame. As soon as the wound is healed the limb may be released daily from its bandages and gentle active movements encouraged, the patient remaining on the frame for three weeks longer. He may then be allowed to walk a little, the amount of exercise being gradually increased. Massage may be applied when

the wound is healed, but passive movements must only be of the nature of gentle stretching of the stiff soft parts. The opposite limb must also be considered, and faulty attitude corrected as described earlier.

This operation (**Arthroplasty**) is suitable when the acetabulum and head of the femur have not been destroyed. In the case of their destruction it is of course found, on opening up as described, that no restoration of the joint, as such, is possible. In these circumstances the femur is separated from the ilium with a saw or chisel, dividing the remains of the neck of the femur so as to leave a raw bone surface on the ilium pointing a little downwards. The flap, consisting of trochanter and attached lesser glutei, is then turned in, so that the trochanter is in apposition with the raw surface on the side of the ilium. The trochanter is fixed in its new position with screws or nails driven through its anterior and posterior edges into the ilium. The object of the procedure is to interpose it between the shaft of the femur and the ilium so as to prevent fresh bony union and to form a false joint. The upper end of the femur, now deprived of the head, neck, and part of the great trochanter, is rounded off and allowed to come in contact with the outer surface of the trochanter in its new position. The gluteus maximus is sutured and the wound closed. The limb is put up on the abduction frame in full abduction to keep the femur from slipping out of position. It should be kept unmoved for a month, after which gentle, active movements on the frame may be encouraged. At the end of two

months a Thomas caliper walking splint may be applied, and the patient begins to learn to walk with assistance. Progress will be slow on account of the double affection of the hips, but there is a good prospect that the false joint will be efficient enough to allow walking with the aid of a single stick eventually.

Affections of the Neck of the Femur.

Mal-union.—This will always be of the type of coxa vara, with limited abduction and shortening of the limb. It will be found by measurements that the top of the great trochanter is correspondingly raised as compared with the sound side. X-rays will show a reduction of the angle formed by the neck and shaft of the femur, and the neck will appear shorter. The case will usually be seen at a time when the union is fully consolidated. The treatment will vary according to circumstances. We are dealing here with a healed compound fracture and not with a typical coxa vara from epiphysial strain, etc., which latter condition would be dealt with on accepted lines. In the present circumstances the lesion is not likely to be progressive, and if function is fairly good and the patient does not complain of disability, nothing need be done. If, however, there is a crippling degree of loss of abduction, or if pain is complained of, an operation is indicated. This will consist of a wedge-shaped osteotomy as described under **Ankylosis** (*q.v.*), or subcutaneous osteotomy with saw or osteotome.

Ununited Fractures of the Neck of the Femur.—These

may be divided into two classes when resulting from gunshot wounds—

(*a*) When the joint is intact.

(*b*) When the joint is destroyed.

In the former case union with a movable hip-joint is sought, in the latter case one aims at bony ankylosis between the femur and pelvis—

In either case the degree of previous suppuration and the length of time since healing was complete are important factors. As the patient can be made to walk without operation, it is far safer to fit him with a Thomas Walking Caliper (Fig. 19, p. 83) and allow him to leave hospital until healing has been complete for a year. Some shortening is necessarily present, and if this is not too great to interfere with walking, it is better not to compensate it with a raised boot, as the shortening will induce tilting of the pelvis, which will be beneficial in giving greater support to the pelvis from the shaft of the femur. After a year from healing, the operation may be regarded as reasonably safe.

Operation on Neck of Femur.—(*a*) *When the joint is intact.* The anterior incision as for excision may be used. The sartorius and tensor fasciæ femoris are separated, then the rectus femoris and gluteus minimus, and the neck exposed. The broken portions are freshened with a mallet and heavy chisel, the raw surfaces brought into apposition and held in contact by a nail, screw, or bone-graft driven upwards and inwards through the great trochanter and engaging the fragments. The length of the fixing agent

must be carefully gauged to avoid its entering the pelvis. It is most important that the limb should be rotated internally to get good apposition.

The patient is placed on the abduction frame for six weeks without movement. He may then get up, wearing a plaster spica bandage reaching to the foot and well moulded round the hip, or a Thomas hip splint, in either case with good abduction. Crutches are necessary and a patten on the boot of the sound side. This apparatus should be retained for three months, then a walking caliper is to be used for a further three months. It may seem that these precautions are excessive, but it must be remembered that the neck of the femur has to bear a great strain.

(*b*) *When the joint is destroyed.* The external incision is perhaps the best, but it must be of good length. Exposure is obtained as described under **Arthoplasty** by turning up the great trochanter and lesser glutei. A slight hollow is gouged in the region of the acetabulum. It is well to give it an overhanging margin to engage the femur. The inner side of the end of the femur is freshened, placed in the prepared space and fixed by two nails, screws, or bone pegs, special care being taken that these do not enter the pelvis. Since the femur has been pushed somewhat upwards and inwards in fixing it to the pelvis, the former position of the slice of trochanter will now be too high for it. A new raw surface should be prepared for it at a suitable level on the outer aspect of the femur, and it should be fixed with two nails or screws. It need hardly be said that the limb should

have been fixed in abduction, extension, and slight eversion. Union should be complete after six weeks on the abduction frame, but the limb should not carry weight without support for many months.

Mal-united Fracture of the Shaft of the Femur.—Before discussing these cases it may be well to reiterate what has already been said, that no bone operation should be undertaken without a good working knowledge of what may be called the **higher aseptic technique.** The degree of ordinary sound asepsis which turns out good results in 100 per cent. of abdominal cases is by no means sufficient in dealing with *un*-infected bone; and this statement applies with far greater force when there has been a previous suppuration with many germs perhaps lying latent but ready to spring into fresh virulence at slight provocation. In no region of the body are these remarks so relevant as in discussing open operations on the femur, since in the most skilled hands the exposure, the amount of trauma, and the time occupied are considerable. For these reasons sound judgment will often induce the most experienced surgeons to let a moderately bad result alone rather than subject the patient to real danger of life as well as limb. If, then, the case is one demanding open operation, by which is meant, on this occasion, an operation with exposure of the bone to the view, it should be undertaken only by a surgeon who is familiar with this class of surgical work. If, then, operations are described here for the sake of completeness and interest, the conditions

under which they are recommended should be firmly borne in mind.

Definition of Mal-union.—Union of a long bone without an open operation is rarely anatomically perfect. Fortunately an anatomically perfect result is unnecessary, and the object of treatment of a fracture by splints is to aim at anatomical perfection and to succeed in functional perfection. The latter is rarely impossible under suitable conditions.

Mal-union, therefore, is a question of degree, a measure of the failure to obtain a functionally perfect result, as regards the bone itself. Mal-union may interfere with function in three ways—

(*a*) By loss of length, due to overriding of fragments, or angulation.

(*b*) By loss of correct alignment from angulation or obliteration of the normal curves. This interferes with the lines of pull of muscles and throws the joints of the limb out of their normal planes of action.

(*c*) By rotation deformity of one fragment on the other, which has the same bad effects as incorrect alignment.

It is quite impossible to lay down any definite rules as to the degree of mal-union which justifies interference. Small degrees of shortening are unimportant, and even with shortening up to one, or even one and a half inches, a suitable and inconspicuous alteration of the boot will reduce the working loss of length to an amount which is bearable and to be preferred in many cases as an alternative to operative intervention. At the other end of the scale are cases with

three or four inches of shortening from overriding, bad alignment, and inward rotation of the lower fragment with the leg and foot. These cases cry aloud for treatment. Another factor which must be considered is the degree of consolidation. If the fracture is at a stage when manipulation alone can do good, one would naturally be inclined towards interference of this kind in a case which with complete union might well be let alone.

Mal-united Fracture with Incomplete Union.—Union may be regarded as incomplete if there is local pain on use and in testing for firmness of union, and local tenderness on pressure. These are signs of exuberant soft callus, which disappears with sound bony union.

At this stage of pain and tenderness, the fracture may be broken down by manipulation, and this should be done if the position is such that a bad functional result is otherwise to be expected. There is no danger of breaking the bone elsewhere, it will give way at the weakest point. The real danger to be considered is that of lighting up old sepsis (see previous remarks on this point). The first movement towards breaking down should be in the direction of increasing the deformity. Thus, if the ends of the fragments point outwards as shown clinically and by X-rays, the knee should first be carried inwards until the union yields and then outwards and so on, until there is complete freedom between the fragments. Consideration must, of course, be given to the position of important vessels and nerves.

Serious shortening must be dealt with by immediate

block pulley extension (Fig. 2, p. 28). The trunk is fixed by a perineal band on the affected side fastened to the table near the patient's head, or, if the table cannot be rendered immovable, to the wall behind the patient's head. A skein of wool is looped round the thigh just above the knee and attached to a block pulley fixed to the wall beyond the patient's feet. The arrangements for this should be worked out before starting to operate, as half-hearted measures with improper fixation are useless. The surgeon steadies and guides the limb while an assistant actuates the pulley. The counter-extension at the

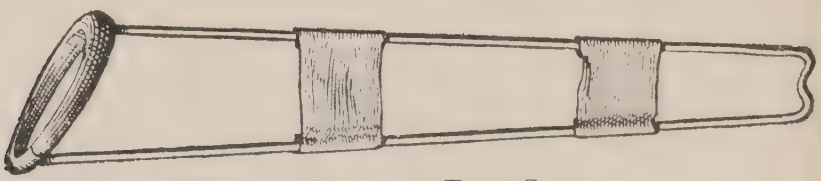

FIG. 22.—THOMAS BED SPLINT.

perineum should be watched to see that there is no slipping or injury to soft parts. The perineal band should be well padded. There is no danger in stretching the soft parts and removing overriding to the extent of at least two inches.

When this is done the limb is put up in a Thomas Bed Splint (Fig. 22). Extension strapping is applied from the lower part of the thigh to the ankle, and continued downward as straps on each side by folding it with the sticky side in. A wooden stirrup is not needed with this splint. The upper ring of the splint is pushed well home against the tuber ischii and the ends of the extension tied together round

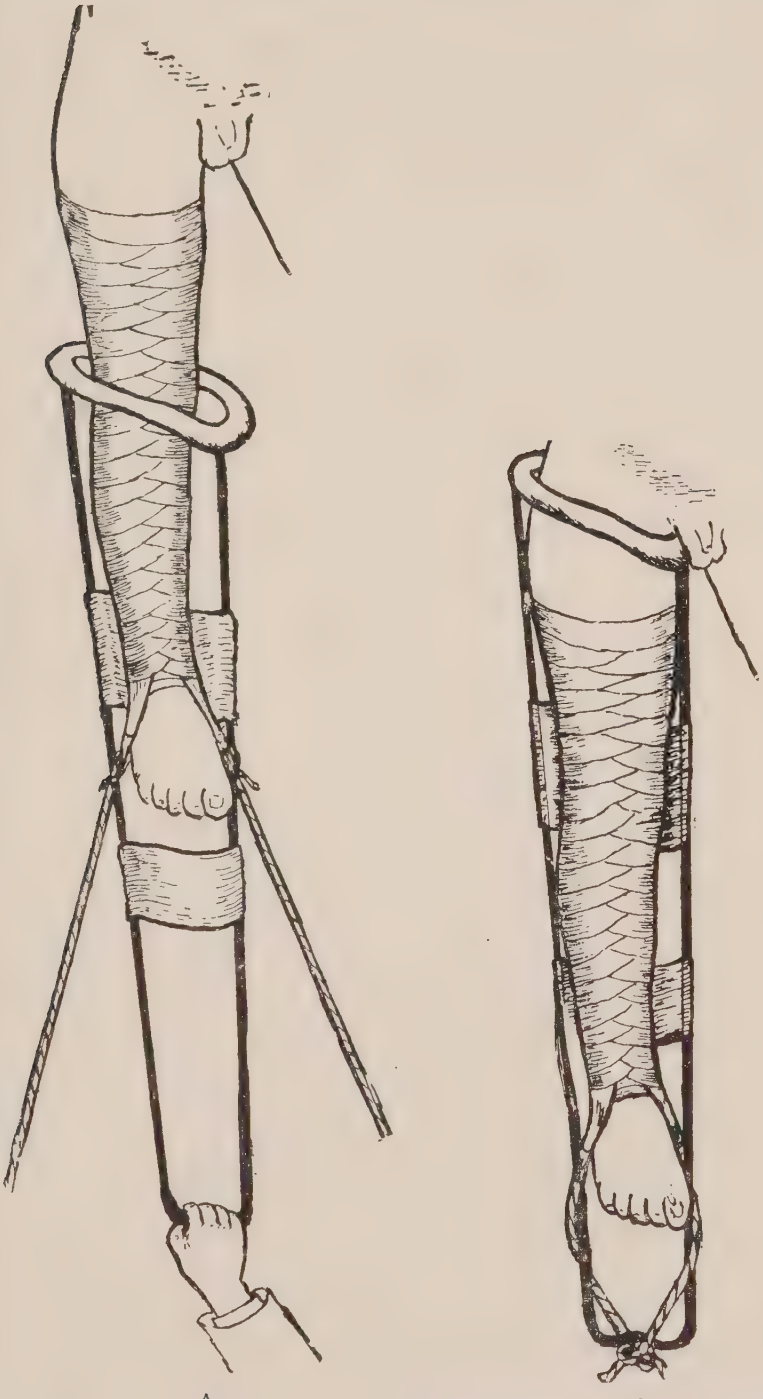

FIG. 23.—APPLICATION OF THOMAS BED SPLINT.

the dip in the lower end of the splint, the limb being at the same time pulled down as far as possible. Rotation is corrected by passing one of the extension bands behind the side iron of the splint and the other in front of the opposite one before they are brought together at the end (Fig. 23, A and B, p. 103). It is most important in this case, as in all other fractures of the femur, to prevent backward sagging of the thigh.

Stout calico strips are fastened across behind the thigh from one side iron to the other, and these are adjusted until there is a slight forward curve of the thigh corresponding with the normal anterior convexity. Any lateral deviation is controlled by similar bands passed round the limb and the appropriate side iron. If the splint is correctly applied in this way local splints to control movement are rarely necessary.

In special cases one or more metal gutter splints (Fig. 1, p. 23) may be added. In a day or two the extension straps are untied and further tightened while the limb is being pulled upon. In this way soft parts are gradually stretched and shortening overcome. It may be necessary to use the pulley extension under anæsthesia again once or more to obtain full restoration of length. The method of "damming" described elsewhere (p. 31) should be used to stimulate bone formation.

As soon as there is apparently firm bony union, the patient may be allowed to get up on crutches, still wearing the same splint, and with a patten on the opposite boot to let the damaged limb swing free of the ground. Six weeks later the "bed splint"

may be replaced by a walking caliper (Fig. 19, p. 83), which the patient should wear for six months. Emphasis is strongly laid on the importance of preventing strain from bearing on the union too soon. Many good results have been spoilt by too early weight-bearing in simple or compound fractures, with or without operation. Full bony consolidation is often retarded for a long time after union seems firm on clinical examination. Each femur has in turn to bear the whole weight of body above it in walking and other movements, and it is nowhere so important as in the case of the femur to allow a wide margin of safety by maintaining the use of a splint of the caliper type for many months, perhaps a year, especially when there is the slightest deviation from complete end-to-end apposition or from correct alignment. Any previous condition of sepsis of the bone lends great additional weight to the argument for prolonged support.

Mal-united Fracture of the Femur with Complete Union.—The union may not only feel firm, but there may be no local pain or tenderness, in which case it may be regarded as complete. X-rays will possibly confirm this by showing a stout bridge of bone between the fragments. In these circumstances manipulation is useless and dangerous. A greater degree of deformity and disability will have to be present to point to the necessity of breaking down the union, which in this instance must be done by obtaining access to the bone. Mere faulty alignment may be treated by a simple osteotomy through the angle, or

in more severe cases by removal of a wedge of bone. If there is overlapping and shortening, the union may be divided by an osteotome or Jones's Blunt-ended Osteotomy Saw (Fig. 24). This may be done through quite a small incision without exposing the bones to view. Due regard must be paid to the position of the main vessels and nerves, but the lower fragment is usually on the outer side of the upper, in which case the saw is entered on the outer side of the upper fragment, and by working toward the side of the lower fragment the saw is kept well away from

FIG. 24.—JONES'S OSTEOTOMY SAW.

any important structure. When the saw has done its work the fragments are freed thoroughly by manipulation, the wound is closed, and further treatment by pulley extension, etc., is carried out as described above. In the case of simple angulation it is as well to use the pulley, as at least one group of muscles will need stretching.

Where there is great overlapping with much new bone formation, the above procedure will not be efficient, and indeed osteotomy with division of the fragments may not be possible. In these circumstances a free exposure with separation of the fragments, freshening the ends and suture with Lane's

plate, may be deemed desirable. The operation is formidable, except in the most experienced hands. When this is undertaken no result short of almost complete restoration of length and alignment is to be considered satisfactory. It should never be undertaken until the wound has been soundly healed for at least six months. A course of heavy massage should then be gone through as a test of the absence of latent sepsis. If there is the slightest inflammatory reaction, as shown by pain, heat, redness, or swelling developed locally, the time of operation must be deferred until a further test leads to no such manifestations. The test may even lead to a breaking down of the scar, which will show that operation must be deferred for a long time. In the absence of any reaction the operation may be proceeded with, under all the rules of the most rigid asepsis. Nothing which has been touched, even with the gloved hand, must enter the wound, the knife used in the skin incision must be discarded and the surrounding skin at once protected with "tetra" or extra towels. All instruments must be of large size and heavy type to cope with a heavy task. They must be handled by the handles only. Blades or points should never be touched with the gloved hand. It might be safe to do so, but the object is to eliminate all possibilities of infection. In any operation, and especially one upon bone, a glove may be easily torn or punctured. In cold blood one may perhaps carefully inspect the glove before letting it touch the tissues, but in a difficult crisis of the operation such a precaution might

easily be forgotten. It is therefore just as necessary for the surgeon and his assistants to drill themselves in aseptic technique before such operations as it is for the soldier to be drilled before going into action. The aseptic habit must be acquired by long practice until it becomes unconscious.

Operation for Plating Femur.—No detailed account is possible here. With all the precautions referred to above, the bone is exposed by a long incision on the outer side. Soft parts are stripped off the shaft, above and below, with a special elevator, and the shaft gripped, above and below, with very powerful bone-holding forceps. The vicious union is divided with a chisel, and the fragments are fully freed by movements of the bone-holders while an assistant manipulates the leg. Fresh surfaces are prepared in different ways according to whether the fracture is transverse or oblique, the amount of bone lost, etc. Let it suffice to say that with obliquity of fracture full length can be regained, and that if the fracture is transverse the final shortening should be negligible, apart from loss of bone.

The limb below the fracture is then boldly adducted inwards until the fragments are at right angles to each other, being still held by the surgeon and an assistant using the bone-holders. The raw surfaces are engaged in this position, and while they are steadied in this position the limb is cautiously and slowly straightened so that the raw surfaces are brought face to face. Rotation must be corrected at the same time. The shortened adductors are fully

stretched by this manœuvre, which is the key movement of all these operations. Perfection of position and alignment must be aimed at, and prolonged attempts with expenditure of time and patience may be needed to get a satisfactory result. When this is attained, the fragments are plated with a Lane's plate with six screws above and below the junction. These are of a special pattern, and should be chosen and fitted, and a drill of the right size selected, before the operation is begun. The operation involves much expenditure of physical energy, and should never be undertaken without at least three assistants. This brief and inadequate description will at least indicate that the operation must be thoroughly understood beforehand, and is not to be undertaken lightly. The muscles and fascia are closed with continuous catgut sutures. The limb is put up on the Thomas Bed Splint (Fig. 23, A and B, p. 103) as previously described. After six weeks, if union seems sound, the patient may get up on a Thomas Knee Splint (Fig. 25, p. 113) with a patten on the opposite boot and crutches. At the end of another six weeks a Caliper Splint (Fig. 19, p. 83) may be applied, and this should be used when the patient gets out of bed for a further three months, so that it is six months from the time of the operation before the limb may be used without support. Splints may be removed daily for massage and movements of the knee-joint after six weeks from the operation, if all goes well. It is essential to a good result that the after-treatment should not be hurried.

Mal-united Fracture of the Lower End of the Femur.

Cases of this type come into a class by themselves if the knee-joint is involved. There is usually great stiffness or ankylosis of the knee-joint in the cases seen at a late stage, with bad alignment. They are often the result of a difficult but successful struggle to save the limb. If the deformity is slight a caliper splint may be ordered with suitable straps at the knee to tend to correct the faulty alignment. The treatment of the stiffness of the knee-joint will be referred to under that heading. In cases of markedly bad alignment a linear or wedge-shaped osteotomy of the femur near—but not at—the site of injury may be called for. After-treatment is on the lines already indicated.

Ununited Fracture of the Femur.—An X-ray examination, with front to back and lateral skiagraphs, is essential. In the case of gunshot fractures, non-union is due to want of fixation, prolonged suppuration with necrosis, malposition of fragments, interposition of soft parts, loss of bone substance, or any of these factors combined. Although the present work is intended to deal primarily with old-healed gunshot injuries, yet non-union of bone is so much related to the presence of chronic sinuses that it is necessary to make a brief reference to the latter here.

In this connection the possibilities are four in number, namely—

1. Good apposition with chronic sinus.
2. Good apposition with wound healed.
3. Bad apposition with chronic sinus.
4. Bad apposition with wound healed.

As treatment varies according to the condition present, these will be discussed in order.

Good Apposition with Chronic Sinus.—X-rays may show some cause of delay in healing, such as dead bone or the presence of a foreign body. It may be possible to deal with the condition present with a sharp spoon after enlarging the mouth of the sinus. The position of the fragments should not be disturbed. If it is certain that all pockets have been opened up, the whole cavity may be filled with Morison's paste, commonly known as Bipp, with the prescribed technique. If this point is doubtful, Bipp should be merely rubbed into the surface. The author has seen disastrous spread of suppuration as the result of blocking the aperture in these cases, leaving untreated pockets inside. A single scraping, as described, will often bring about complete closure of the sinus. In other cases the sinus may be completely excised, with good results. The fracture is treated by simple immobilisation on the Thomas Bed Splint (Fig. 23, p. 103), with the usual fixed extension, and support for the thigh to preserve the normal forward bowing of the femur. Healing may occur before union, or union before healing.

Local congestion (the damming method of Thomas) is most valuable at any stage (see Introduction). This method of stimulating osteogenesis may be carried on in conjunction with any other necessary measures until union is complete.

Good Apposition with Wound Healed.—The treatment of this condition continues on the lines laid down

under the previous heading. It is important to see that there is no circular compression interfering with circulation, apart from the deliberate intermittent interference by damming. If the treatment already indicated is carefully carried out, eventual good union is almost certain. It should be remembered that slight movements, and not violent ones, are the factor predisposing to delay in union, and the conditions of splinting must be carefully reviewed in case of delay, so that perfect immobilisation may be assured. Fresh skiagrams should be taken, which may show some progress in bone formation, or indicate some cause for the delay. It is difficult to give any date for active interference, but this should certainly not be within six months of the healing of the wound. Even then a preliminary test by vigorous massage is essential, as mentioned under the heading of Operation for Plating the Femur. The subsequent procedure will be on the lines there indicated, the ends of the fragments being freshened with a saw and fastened together.

Bad Apposition with Chronic Sinus.—Here the radiograms must receive careful study, as the problem is often a very complex one. Sources of suppuration must be removed, the exact procedure varying according to the relations of the fragments.

Firstly: Owing to destruction of bone, the ends of the fragments, though of good shape, may not meet each other; that is to say, there is an actual gap in spite of good alignment. There is here a choice between getting the wound to heal without shortening

of the limb, with a view to bone-grafting six months later, or, as an alternative, allowing the limb to shorten enough to bring the ends of the fragments together. The author has tried the latter plan with good results as regards union, and thinks it preferable where the shortening will not amount to more than 1 to 1½ inches, which can be compensated by a neatly made thick boot. The approximation of fragments is brought about by relaxing the foot extension on the Thomas Bed Splint. Where the gap is larger, it is advised to get the patient up on crutches and on extension in a Thomas Walking Splint (Fig. 25) with a patten on the boot of the sound side, and discharge him to return to hospital for a bone-grafting operation six months after the wound is soundly healed. In this case it is important to see that extension is maintained in the interval.

FIG. 25.—THOMAS WALKING KNEE SPLINT.

Secondly: The fragments may meet, or even overlap slightly, but the ends come into points which could never lend themselves to sound union. In this case also the

patient must be discharged for six months, wearing a splint of the same kind as above and with the same precautions.

Thirdly: There may be overlapping of well-proportioned fragments, which promise to unite if brought end to end. It may be necessary or easy to expose the ends in removing a source of suppuration. If so, the fragments may possibly be manœuvred into apposition at the same time, with or without the aid of pulley traction. If X-rays have shown more than a minor degree of overlapping, it will be a good plan to fix the pulley apparatus before beginning the operation, so that some pulley traction may be used if required. A warning is given against anything in the nature of a breaking-down operation at this stage. A drainage tube should always be used if there has been the smallest disturbance in the relations of the parts inside. The manœuvres suggested are of the simplest. No interference with callus is permissible and no opening up of surrounding tissues. In any case which does not lend itself to simple adjustment of this kind, the only course to pursue—and this will be the usual one—is to treat the sinus alone, and then to go on with extension on a Thomas bed, or walking splint, with opposite patten, until the wound has been healed for six months. After this the procedure will be as for mal-union with overlapping, if the latter has not been reduced meanwhile.

Bad Apposition with Wound Healed.—The treatment is indicated in the preceding paragraphs. No open operation should be performed within six months

of healing, and then only after preliminary heavy massage gives no inflammatory reaction. Overlapping may, however, be dealt with by manipulative measures, as described under "Mal-union," when three months have elapsed, if massage gives no bad results. Percussion is of great value here. When the soft callus has been broken down, the broken ends are turned towards the skin at a healthy spot, *i. e.* not at the scar, and they are beaten with a mallet. The pulley is then used and the Thomas splint reapplied, continuing as in mal-union, with damming, further extension, and so on as before. Open operation will rarely be necessary. In the cases where length has been preserved at the expense of union, or in those with two-pointed fragments which cannot be expected to unite, bone-grafting will be necessary after six months or more. The method is similar to that which is to be described under the heading of "Ununited Tibia." A lateral Lane plate as an internal splint will be found almost essential.

As will be seen from the foregoing remarks, the circumstances will often be such that a long time must elapse before any operation can be undertaken. If under these conditions complete rest in bed is not likely to lead to early union, it may sometimes be thought advisable, for the sake of mental and bodily fitness, to allow the patient to walk in a caliper splint during the period of waiting. No relaxation of splinting precautions must be allowed, massage should be used as far as possible and damming

persevered with. The amount of exercise allowed will improve the general health, as well as the local condition of the limb, and in some cases will actually promote union.

The Knee-Joint.

Since the theme of this work is the treatment of various orthopœdic disabilities due to gunshot injuries, it does not come within its scope to deal with the majority of derangements and injuries of the knee which are common to civil and military life. For an account of these the reader is referred to other works.

The orthopædic aspect of old gunshot wounds may be discussed under the headings of Chronic Synovitis, Deformities and Interference with the Range of Movements, in the direction either of Reduced or Abnormal Mobility.

Chronic Synovitis.—This is not at all uncommon in connection with previous wounds of or near the joint. There is often some deformity of neighbouring bones, such as shortening or bad alignment of femur or tibia, which places some undue strain on the ligaments of the joint, and so leads to effusion. Treatment is obviously to be directed to the rectification of the deformity by operation, splinting, or adjustment of the boot in height or direction of tread. For instance, if there is an inoperable shortening of the limb, the boot must be correspondingly raised; if there is clearly a strain on one side of the joint, the sole of the boot should be raised on its corresponding

half of the sole, so as to throw the weight more towards the opposite side of the limb. Apart from dealing in this way with the cause, no specal treatment of the synovitis is necessary beyond rest and firm elastic pressure. The synovitis is of the type which disappears with rest and returns with exercise. Tight bandaging is the method of applying elastic pressure. Unfortunately, a bandage round the limb which is tight enough to give efficient pressure is usually so tight as to be uncomfortable, to limit movement unduly, and to interfere with the circulation in the leg. To meet this difficulty the author has devised a Synovitis Pad (Fig. 26, p. 118), which may be found useful in such conditions, and in any where elastic pressure is desirable. It is made of thick felt covered with leather. There is a hole for the patella, to prevent injurious pressure of the patella on the femur. Otherwise the pad covers the whole of the front of the joint and extends for three inches above and below the patella. It folds round the joint as far as the inner and outer hamstrings. It is to be fastened by four straps, which pass right round the limb, but hardly interfere with the circulation, owing to the gap at the back which is bridged by the straps without pressure on the popliteal space. The straps above the patella are intended always to be kept as tight as possible; those below the patella may be adjusted according to the degree of flexion which is thought desirable. It has been found very efficient in reducing or keeping down effusion.

Apart from such extrinsic causes as have been indicated, synovial effusion is very common in connection with direct gunshot injuries of the joint. The effect

Fig. 26.—Synovitis Pad.

may be due to the actual presence of a foreign body in the joint, and this should usually be removed. In the majority of cases, however, the fluid is associated with one of the conditions which lead to interference with range of movement, such as old injuries of the

articular cartilages, old arthritis, etc., and its treatment will be discussed in connection with these.

Deformities of the Knee-Joint.—These are really deformities of neighbouring bones, but it will be convenient to consider them in their effects on the joint.

Genu Valgum.—This is usually due to a mal-union of the femur near its lower end. If consolidation is incomplete, as shown by the presence of imperfectly healed wounds, local pain, or tenderness and exuberant callus, a Thomas walking splint should be used, with straps to pull the knee towards the outer bar. The patient may get up with crutches and a patten on the opposite boot. Later, when reduction is accomplished, a Thomas caliper is used, with similar straps to maintain the reduction. When consolidation is complete, perhaps three months later, the caliper may be discarded, and the patient may walk without a splint, but with the sole and heel raised on the inner half to throw the weight outwards.

If there is a crippling deformity which cannot be thus reduced, a corrective osteotomy may be necessary six months after healing is complete. The actual site of the fracture should be avoided if possible, for fear of lighting up suppuration. The osteotomy saw (Fig. 24, p. 106) is well adapted for this purpose.

Genu Varum.—This may be from the same cause, and is treated on identical lines from the opposite aspect of the joint, as regards splinting or operation.

It is also frequently due to mal-union of the tibia, with shortening, and will be referred to under that heading.

Genu Retrorsum.—Back-knee is a very unsightly deformity and impairs very much the strength of the limb. It is usually the result of mal-union of the femur or tibia. The loss of normal anterior curves, and still more the presence of an anterior concavity, throws the knee-joint behind the centre of gravity and puts tension on the hamstrings and the posterior ligaments of the joint, thus exaggerating the original deformity. The secondary stretching can be rectified by raising the heel of the boot of the affected side for half an inch. This makes the patient stand with the knee slightly flexed. If there is already a shortening of the limb, this must be compensated by raising the whole sole and heel before adding the extra half inch to the heel. This treatment may be supplemented if necessary by applying a Knee Cage (Fig. 27), with a stop to prevent full extension. These methods are particularly suitable at stages when operation is not yet safe, for reasons of present or threatened suppuration. Mal-union must, of

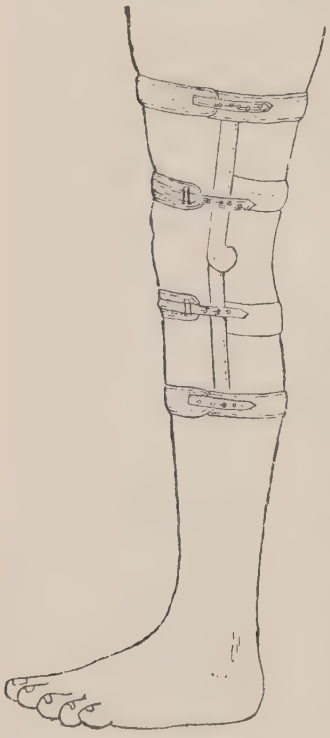

Fig. 27.—Knee Cage.

course, be dealt with on the lines indicated under that heading. If for any reason it is not thought wise to interfere with the mal-union, the alignment may, in these cases, often be rectified by removal of a small wedge from the back of the femur above the knee-joint. This will prevent the knee from going so far backwards in full extension. The limb is then put up as fully flexed as circulation will permit on a back splint, with gutter pieces behind the thigh and leg (Fig. 28). Walking with the cage and raised heel may be allowed in six weeks.

Fig. 28.—Gutter Knee Splint.

Interference with Range of Movement of Knee-Joint. The Ideal Position.—Attempts to convert an ankylosed joint into a movable one by operation have not been encouraging in the case of the knee. The joint resulting has always proved to be weak or painful. As weight-bearing is the most important function of the joint, it is essential in cases of certain, or threatened, ankylosis to see that union takes place in the best position for this end. The completely extended position is recommended. A slight degree of flexion would give a better appearance, and perhaps be a little more convenient, but this is found almost impossible to maintain. The body weight and the pull of the hamstrings will always

tend to increase the flexion, and any attempt to obtain this slight degree of flexion is generally followed by the necessity at a later date of an excision of the joint to straighten the limb. The normal line of the fully extended limb will, therefore, be assumed to be the best possible.

Bony Ankylosis.—If the limb is ankylosed in the extended or slightly flexed position, no operative treatment is needed. In the case of slight flexion the patient should wear a Thomas caliper (Fig. 19, p. 83) for at least six months after healing and union are complete clinically, to reduce the weight on the joint and the tendency of the soft bone to yield in the direction of further flexion. A leather knee-cap should be worn to aid in this by preventing the knee from coming forwards.

If there is any crippling deformity, either antero-posterior, or lateral, operation may be needed sooner or later. It is well to defer such for from six to twelve months after healing is sound, to avoid the lighting up of old suppuration, especially if an excision of the joint is necessary.

Meanwhile the patient may be allowed to get about, or to be temporarily discharged from hospital, wearing a Thomas walking splint and using crutches. Straps are applied to the joint and side bars to pull it in the required direction, and these may bring about decided improvement while the union is soft. Great degrees of deformity of the knee are rare under the careful treatment which the patients have received during the early stages.

As regards the nature of the operation to be performed, excision of the joint is very rarely necessary in these late cases. Its place may nearly always be taken by a simple linear osteotomy with the Osteotomy Saw (Fig. 24, p. 106) made just above the condyles of the femur. It should always be the operation of choice, as it is simpler, quicker, and less dangerous. The after-treatment is on a bed splint, in a recent fracture.

Fibrous Ankylosis.—This will be indicated by rigidity of the joint, with a narrowing of the space between the bones, as shown by X-ray, due to destruction of articular cartilage. It is usually the terminal stage in a case of survival after a septic arthritis. There is most commonly a position of partial flexion, which must be corrected. It is safer and more satisfactory to straighten the limb by gradual methods if possible. Slight flexion is best reduced on the Thomas Bed Splint (Fig. 22, p. 102).

The method is as follows—

The splint is slipped on and held up. A wide flannel bandage is tied to the outer side bar, just below the top ring. Several turns of the bandage are passed lightly round the two bars down to the level of the knee. This is to form a layer for pressure on the front of the thigh, which is to be protected with plenty of cotton wool. The foot is then lifted up, between the side bars of the splint, and the same flannel bandage is continued down to the foot, but now **behind** the leg which is also protected with a layer of cotton wool between the bandage and the

calf. When the foot is reached by the bandage the condition of things is that there is a layer of bandage pressing on the front of the thigh and another pressing on the back of the calf, with a resultant effect of tending to straighten the knee-joint.

The interrupted back splint shown in Fig. 28, p. 121, may also be used for this purpose. The splint is bent at such an angle that when it is put on there is a space between the back of the knee and the bar of the splint.

The front of the knee having been protected by a thick layer of cotton wool, it is bandaged down to the splint as firmly as can be borne. By the following day the joint will probably have yielded a little, and another bandage may be applied, and so on until the knee is straight.

Where there is considerable flexion deformity these splints are less satisfactory for mechanical reasons. Here the Turner Splint (Fig. 8, p. 54) is valuable. The splint is adjusted to the angle of the joint, and is fixed in place by the application of separate plaster-of-Paris bandages round the thigh and leg pieces, the knee being left uncovered.

The plasters must take their bearings from the foot and the ischial tuberosity to prevent slipping. By means of the screw adjustment the angle of the splint is increased a little day by day, and with it the angle of the knee-joint. This type of splint is superior to any other for gradual adjustments of the knee or elbow joint and is of use in many varieties of stiffness.

When the limb is straight it should be kept so in a Thomas bed splint for a month. After this the patient may walk in a caliper splint, which is taken off at night. Nothing is gained by attempts to turn such a joint into a movable one by manipulation if the diagnosis has been correctly made by X-ray. Any small degree of movement which is ultimately possible is more likely to be attained by leaving it alone in the straight position. In course of time the patient may find that he can move the knee through a small range from full extension when he takes off the caliper, which should be worn through the day for a year while he is going about his business.

False Ankylosis.—This rather vague term may be taken to include all cases of a stiff joint in which the condition arises from anything short of fibrous ankylosis. The definition, imperfect though it is from the pathological standpoint, is useful in indicating a condition in which there may be a reasonable hope of obtaining a joint with a greater or less degree of movement. The stiffness may be due to adhesions at one or more points within the joint, or to former suppuration in the surrounding tissues. The X-rays may show what appears to be a normal joint, or perhaps a local haziness or break in the regularity of the joint outlines. Rigidity will rarely be absolute. There will be a little "give" in passive movement, though no active movement may be present. If there is any abnormality shown by X-rays, the Turner splint (Fig. 8, p. 54) is to be advised here. It may be adjusted alternately in

the direction of flexion and extension, being moved through a few degrees at each change. It will probably result in obtaining a joint with some range of movement in a short time. It is essential for function that this range should include full extension. When this point is reached, massage and active exercises may be started. The exercises should be begun on a small scale, watch being kept for any inflammatory reaction which would indicate that the exercises are being pushed too fast. In this case rest must be ordered until the inflammation has subsided, when a cautious fresh start may be made. Time and use will probably do more than mere active measures to bring about the best result possible in the case.

On the other hand, if the joint outline appears normal in careful comparison with the healthy joint of the other side, and has no thinning of the cartilages, as shown by narrowing of the space between the bones, it will usually be safe to proceed with manipulation to break extra-articular adhesions.

Manipulation of Knee-Joint.—Ether is to be preferred to gas anæsthesia, as it gives better relaxation of muscles and allows the procedure to be carried out without undue haste. The patient is turned on his face, with his knee coming to the end of the table, and a firm sandbag supporting the front of the thigh. Great care is needed when the femur has been previously weakened by fracture, suppuration, or prolonged disuse. In such circumstances—and indeed it is always safer—the

femur and leg bones should be protected by gutter splints bandaged on beforehand.

Flexion should be done first. The surgeon rests his forearm along the length of the front of the patient's leg and leans his body against his forearm, throwing his whole weight steadily in the required direction. If the case has been properly chosen, the knee can thus be brought into complete flexion. If it cannot, no greater force is justifiable. Flexion having been obtained, the leg is then brought down into the fully extended position by similar methods. Each movement should be done only once. In extension it should be remembered that the final external rotation of the tibia on the femur is needed to complete the movement. If the movements are obtained easily and without grating, the prospect is good. The knee-joint should be firmly bandaged over a thick layer of cotton wool, and on the following day massage and active movements in bed should be used. If there is no inflammatory reaction, the patient may proceed to use the limb in walking on the second day. In case of slight effusion, the Synovitis Pad (Fig. 26, p. 118) may be useful.

If, however, the manipulation proves difficult, with much resistance and grating, it is useless to push it too far. It is then better to be content with a small range of movement. The joint is bandaged and put at rest. The use of the Turner Splint (Fig. 8, p. 54) for subsequent treatment is indicated.

Limited Movement.—These cases are closely allied to those previously described in their pathology and

treatment. The clinical condition and radiographic findings must be the guide as to whether gradual movement, manipulation, or active exercises are most suitable, when the lesion is in or round the joint. In case of failure to get a good range of movement, the fully extended position must be assured by one of the means described.

Sometimes there is one definite localised obstruction outside the joint, such as the adherence of soft parts to the femur where it has been fractured and united, or a contracted scar in the popliteal space. In the case of adhesions to the site of a fracture, it is of the greatest importance to wait until union is sound. Then manipulation may be used with caution, splints being first applied to the femur to prevent fracture. If manipulation fails, the Turner splint is indicated.

Contracted Scars.—These are treated by excision or by gradual stretching with the Turner splint or by both.

If the scar is excised it must be done thoroughly, with due regard to the important underlying structures. The wound can usually be closed by drawing the skin from the sides. If not, a pedicled flap must be brought across from the side of the thigh. The Turner splint may be needed to complete the extension. When this is attained the limb must be kept fully extended for three months to allow time for the tension on the surrounding skin to become accommodated, as it will. During this time the patient may walk in a caliper splint. Sudden and violent stretching of contracted scars is to be avoided. No

time is gained by it, as it leads to further formation of fibrous tissue, and the subsequent period of fixation in extension has to be prolonged.

The leaving off of the splint must be gradual, and subject to the test of the clinical result. It should first be omitted at night, and then for increasing intervals during the day. Any recurrence of flexion is a definite sign that constant extension must be renewed for a further period.

Undue Mobility of the Knee-Joint.—This is not common as a result of gunshot wound. When there has been great destruction and the limb has yet been saved, a union of the bones with stiff joint has been the usual aim. If there is lateral mobility it may be treated by applying a Thomas caliper or a knee cage (as shown in Fig. 27, p. 120), but with caliper extensions to fit into the heel of the boot. If the condition is so bad that one of these does not meet the case, an excision to obtain a permanently stiff joint may be called for.

Fracture of the Bones of the Leg.—One or both bones may be affected. Fractures of the fibula alone rarely call for special treatment except in connection with Pott's fracture, to be referred to later. Shortening of itself is not often so severe as to call for more than a moderate adjustment of the sole of the boot. There are very few deformities which cannot be thoroughly corrected at a late date, so that, generally speaking, it is well to wait for thoroughly sound healing of wounds before interfering further than by manipulation.

Mal-union of the Tibia.—The common errors are faults of alignment or rotation. While union is

incomplete, as shown by pain in testing the union, or by local tenderness, the deformity can be corrected by manipulation within two or three months of healing of the wound. The bone will yield at its weakest point and fracture of the fibula may be disregarded,

FIG. 29.—SHOE SPLINT.

or may even be a useful help. There is usually a posterior and inward bowing at the fracture, with flat extended foot and contracted calf muscles.

The manipulation should restore the normal slight forward bowing of the tibia and should leave the limb in the smallest degree of bow leg, which is far stronger than a leg bent inward or absolutely straight.

The foot must be brought up to a position of full dorsiflexion. Lengthening of the tendo achillis will usually be necessary, and the use of the Thomas Wrench (see below). Correction having been made, the limb can be put up in the Thomas Bed Splint (Fig. 22, p. 102), combined with a Shoe Splint (Fig. 29, p. 130) to keep the foot in position, or if the fracture is low in the tibia a Skeleton Leg-Splint (Fig. 30) may take the place of both. In any case the back of the leg must

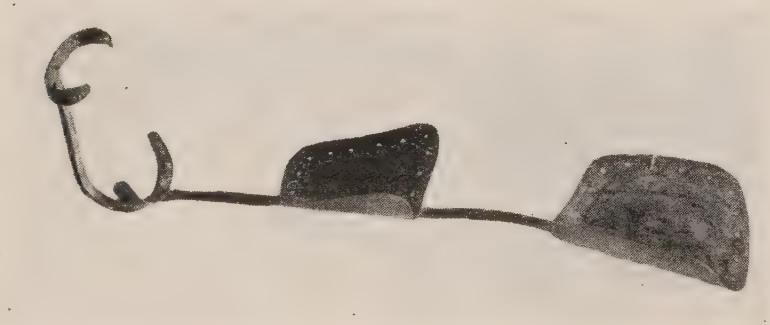

FIG. 30.—SKELETON LEG SPLINT.

be well supported to preserve the forward curve of the tibia. The foot must be kept square or a little dorsiflexed, and the straight line through the inner edge of the patella, the inner malleolus and the head of the first metatarsal must be preserved. Rotation deformity must be looked after.

Where the skeleton splint has been used for fracture, low in the tibia, it is well to replace this by plaster of Paris as soon as possible. This may be done at the end of a week if no inflammation is present, or as soon as this has subsided. The plaster must extend

from the bases of the toes to the middle of the thigh. The same precautions must be taken to preserve the corrected attitude. The foot should be slightly inverted and dorsiflexed. The necessity for having obtained full dorsiflexion is seen, for if this is imperfect the attempt to bring the foot upwards will antagonise the effort to get rid of the posterior bowing of the tibia. The plaster should be worn—renewed if necessary—for two to three months. A short caliper is then used for at least another three months. This ends above in a leather ring bearing on the tuberosities of the tibia and fits below into sockets in the heel of the boot (Fig. 33, p. 142). The sole and heel should be raised one-third of an inch in their inner halves to throw the weight outwards.

In the cases of fracture higher in the tibia, where the Thomas bed splint has been necessary, its use should be continued for two to three months, the patient getting about on crutches after the first month. Later this splint is replaced by the ordinary long caliper (Fig. 19, p. 83), and the patient is allowed to walk with the sole and heel altered as described above.

In cases of union with bad alignment seen at later stages with full consolidation, manipulation is useless and other measures must be taken. These should be as simple as the case permits. A linear or wedge-shaped osteotomy at or near the site of the fracture will often suffice. In worse conditions an exposure of the fracture with reposition and bone-plating may be needed. A linear osteotomy of the fibula at a

higher level is a safe and satisfactory help in any of these corrections.

The precautions against recurrent sepsis, as previously referred to, must of course be taken. Generally speaking the dangers resulting from recurrent sepsis are reduced as one approaches the periphery, where the bones are smaller and nearer the surface.

A special type of mal-union is sometimes seen in which there has been destruction of a small portion of the shaft of the tibia and union with shortening, the fibula remaining of its original length. This results in considerable bowing of the leg and undue prominence of the head of the fibula. The author has found that lengthening of the tibia by operation gives a good result. The fracture of the tibia is usually near its head. The shaft of the tibia is exposed below the lesion by a long flap incision. The periosteum is stripped off and the shaft is sawn half way through from the front above and half way through from the back four inches lower. The intervening portion is split longitudinally with a chisel or saw. An assistant presses the foot outward and the middle of the leg inward while the surgeon slides the fragments on each other, then grips them together in their new relation with bone-holding forceps until they have been secured with two pieces of silver wire passed through holes drilled near the ends of the parts which overlap (Fig. 31, p. 134). An osteotomy of the fibula may help in the correction, but it should be deferred until the stretching is done, as the intact

bone forms a useful lever. After-treatment is indicated above.

Mal-union at the lower extremity of the tibia will be discussed with deformities of the foot.

Ununited Fracture of Tibia.—Non-union of bone has been already discussed somewhat fully. It will be necessary now only to refer to special points in the case of the tibia.

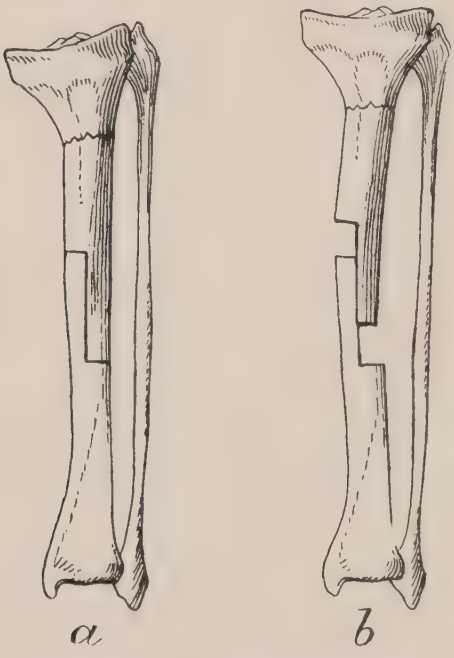

FIG. 31.—BONE LENGTHENING.

Consolidation after union has begun is quicker in the tibia than the femur. It is more easily tested and the fibula acts as a splint. For these reasons the after-support is not needed so long, and when union has appeared to be firm for, say, one month the patient may walk with a light support which will not be needed for more than three months further. The bone is easy of access and consequently most operations are not long or severe. This point brings the balance rather further towards open intervention than in the case of the femur.

Again, owing to the splinting effect of the fibula, a fracture of the tibia with loss of bone is less likely

to come together so as to end in bony union. The fragments are held apart by the fibula.

Therefore, while cases with good apposition are treated on conservative lines by immobilisation, percussion, and damming with a good expectation of success, on the other hand when bad apposition is the cause of non-union, open operation is more often called for than in the case of the femur. Six months is usually allowed after the wound has closed before a bone plating or grafting should be performed. Some consideration must be paid to the duration and extent of the suppuration. If the wound had healed in a few weeks from the time of its infliction, it might well be decided that the suppuration was slight, and such as would be connected with healing by granulation without obvious infection. In these circumstances one might find that in three months there was no inflammatory reaction on testing with deep massage, and proceed with the operation. On the other hand, if there had been prolonged deep suppuration, with numerous sinuses and shedding of pieces of dead bone, one might well pause at the end of six months and postpone operation for another like period.

Bone-grafting in one of its forms is a most suitable operation for non-union of the tibia, whether the case is one where good apposition with all encouragement has failed, or whether, as is more often the case, the ends of the bones have not been, or cannot be, made to meet properly. There are two operative factors to be considered—

(*a*) The procuring and placing of the graft.

(*b*) The subsequent immobilisation of the graft and fragments of the shaft.

There are countless opportunities for the exercise of ingenuity in attaining these two results, and no one method can be laid down definitely as the best. Sometimes the graft itself will provide the immobilisation : in other cases the use of a plate may be combined. Some bone-grafting operations fail for want of that perfect immobilisation which a plate will readily secure. In the case of the tibia, however, the graft alone will usually suffice.

Where there is good apposition, the sliding inlay (Fig. 4, p. 35) is very suitable. Albee's apparatus, with double circular saw, is almost essential for this method. In the absence of the Albee apparatus, a good substitute for the sliding inlay may be found in a lateral sliding graft. Two pieces of bone are removed, with saw and chisel, from the main fragments, of the same calibre but of unequal length. The grafts are easily and rapidly detached, after mapping them out with a series of holes drilled through the compact tissue. The grafts are reapplied in reversed positions, so that the longer graft crosses the line of fracture (Fig. 5, p. 37). In this case it is better to fix with nails or screws. It is a method of plating with a plate of bone instead of metal.

Where there is Loss of Bone, and a space to be filled, grafting by either of these methods is feasible, but as bone is here lacking it is well to take the grafts from the opposite tibia, whichever method is used. The

pieces of bone cut off in freshening the ends of the fragments had better be discarded, as they are of poor quality and may harbour infection ; but those detached in preparing a raw surface for the graft should be preserved and broken into small pieces to help to fill the gap between the ends of the bone. When the graft is fixed the bone should be in firm continuity. If not, the operation is likely to fail. Further security must be sought by fixing the graft more firmly, or by attaching a Lane's plate bridging the gap on the most convenient side of the graft, but not touching it.

The whole limb is then fixed in a skeleton leg-splint with thigh-piece (Fig. 30, p. 131) or other suitable splint. With end to end apposition, union may be gently tested at the end of six weeks ; but if a gap has been bridged, at least twice that time should pass before the question is even considered. The usual conservative estimates of time of union should be doubled, or more than doubled, in the case of bone-grafting. Six months will probably be needed before the patient can put his foot to the ground, even with the support of the short caliper splint.

Deformities and Disabilities of the Foot.

There are three common deformities of the foot resulting directly or indirectly from gunshot wounds—

(*a*) Dropped foot (**Equinus**).
(*b*) Inverted foot (**Varus**).
(*c*) Everted foot (**Valgus**).

Dropped Foot is exceedingly common. It may arise from a number of causes. Among them are—

1. Sciatic or external popliteal palsy.
2. Mal-united fractures of the leg.
3. Injuries and infections of the ankle-joint.
4. Defective posture in association with wounds, especially of the leg.
5. Contracted scars of calf muscles.
6. Wounds of muscles or tendons of the front of the leg.

Treatment.—The treatment of palsies is discussed with nerve injuries.

Mal-united fractures are dealt with on the lines already described.

In cases of involvement of the ankle-joint, the aim is to restore the right-angled position, which is the best one for ankylosis. If the X-rays show bony ankylosis, the joint should be exposed from the front by retraction of tendons and the bones of the joint separated with a chisel. This is followed at once by manipulation as described below. If there is no bony ankylosis, manipulation will suffice. It must not be done until all suppuration has ceased for three months. Ankylosis with the foot at right angles to the leg gives a very useful result. There is little inducement to try to improve on this result by operative measures for this reason and the fact that the gain is problematical.

In all other cases a short time may be allowed for a trial of correction by massage and exercises, combined with splinting in the intervals of rest. The

Shoe Splint (Fig. 29, p. 130) as used for clubfoot is recommended. It is put on, adjusted to the deformed position, and bent up towards a right angle a little each day. Much time should not be spent on cases which are resistant, as the correction by operation is a simple one. This remark applies also to scar contractions of the calf muscles. These are very

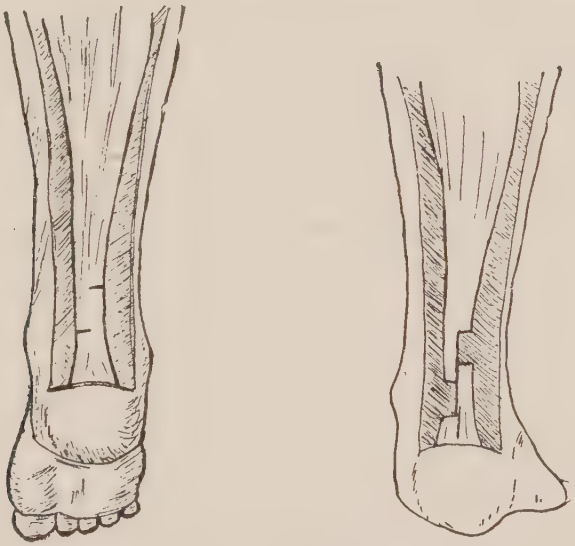

FIG. 32.—TENDON LENGTHENING.

intractable, and it is better to correct by tenotomy and wrenching, now to be described.

Correction of Dropped Foot.—A preliminary tendon lengthening of the tendo achillis is nearly always desirable. Transverse tenotomy is unsatisfactory in adults owing to the length of time before the tendo achillis becomes strong again. With tendon lengthening the tendon is as strong as ever in a few weeks. The sliding method with double puncture is recommended as the simplest (Fig. 32). A short

sickle-bladed tenotome is advised. The point of this is entered through the middle of the back of the tendon near its lower end. The cutting edge is turned to one side, and half the tendon is cut through. It is now inserted again about an inch and a half higher in the tendon, and the tendon is then cut half through in the opposite direction. At this stage the tendon is held between the two cuts only by the adhesion of the longitudinal fibres to each other, so that a comparatively small force will cause these fibres to glide upon each other with a lengthening of the tendon. It may be possible now, by strong dorsiflexion of the patient's foot, by hand alone, to get the tendon to slide and to bring the foot into dorsiflexion. A strong effort is usually needed. If this fails, the Thomas wrench is to be used. (It is shown in its original form in Fig. 35.) With this powerful aid the correction can nearly always be completed. The chief obstruction is often not so much in the tendon as in the ankle-joint and its surroundings. The force required will, therefore, vary, and the surgeon must not be satisfied without a definite yielding sensation accompanied by a tearing sound as the tendon slides.

Full dorsiflexion having been reached, the foot is put up in the Shoe Splint (Fig. 29, p. 130). In cases of threatened ankylosis the splint should be exactly at right angles. In all other cases it should be bent so as to maintain some over-correction. The foot-piece of the splint must be well padded to prevent pressure sores. The splint should be removed in forty-eight

hours to ascertain that there is no undue pressure on any point. In such case the padding of the splint must be adjusted so as not to bear on any point which is discoloured. At the end of a few days the foot and lower two-thirds of the leg may be put in plaster of Paris for three weeks. After this time the patient may in uncomplicated cases begin to walk without special support. This applies to cases due to posture or contractions. In the case of joint involvement a longer period of rest may be needed. Where the deformity has been due to defective action of the extensors, this will have been dealt with if possible at the time of the correction. In any case some support to prevent recurrence will then be needed. Many devices have been used to maintain correction of dropped foot. All are based on one of two principles: (1) providing elastic traction to oppose the action of gravity and the plantar flexors; (2) providing a mechanical block to prevent the foot from falling below the right-angled position.

As a rule in surgical conditions it is desirable that the foot during treatment should never drop below the right angle. The author recommends, as being simple, strong, and efficient, the Dropfoot Splint (Fig. 33, p. 142), as used by him for many years and adopted in Leeds and elsewhere. A short caliper extends from below the knee to the heel of the boot, where it fits into a round socket and allows normal play of the ankle-joint. Plantar flexion is prevented by a stout flange fixed to the heel of the boot and passing vertically upward behind the side bar of the

caliper. The apparatus is easily applied by the patient and not likely to get out of order. So long as support is needed a shoe splint should be worn whenever the dropfoot splint and boot are taken off.

When the extensors are damaged beyond hope of recovery, the method of "tendon fixation" is very

FIG. 33.—"DROPFOOT" BOOT AND SPLINT.

valuable. The tendons of the peronei and the tibialis anticus are divided from the muscles as high as possible. Through an incision in front of the lower fourth of the tibia the bone is exposed, and a large hole is drilled transversely through the front of the bone. The tendon of the tibialis is pulled through the hole from the inner side and the peronei tendons

from the outer side, and the tendons are sutured to each other at such a tension as slightly to dorsiflex the foot. The foot is maintained in slight dorsiflexion on a Shoe Splint (Fig. 29, p. 130) for a month, and the patient may then walk with a Dropfoot Splint (Fig. 33, p. 142). The tendons act as permanent anterior ligaments and help to prevent dropping of the foot.

Inverted Foot (Varus). This may be due to—

Paralysis of the peronei muscles.

Damage to the peroneal muscles or tendons.

Functional or reflex spasm of the invertors.

Contracting scars on the inner side of leg or foot.

Mal-united fractures.

Nerve Palsies are discussed in the section on nerve injuries.

Damage of Muscles or Tendons are dealt with on general lines by suture or tendon grafting.

Functional Spasm of this type is one of the most common of functional war lesions, and is extremely resistant to treatment. There is usually some trifling healed wound of the leg, or there may only have been some injury without breach of surface, in either case of such a nature as not to be the direct or mechanical cause of the deformity. The foot is firmly held in the common clubfoot position, and gives a superficial appearance of some organic lesion. It is found on examination that the foot can, with persuasion and force, be moved towards the normal position if not over-corrected, that the deformity disappears under anæsthesia, and that the evertors react normally to

the faradic current. Various surgical measures, such as application of plaster in eversion, tenotomy, transplantation of the tibialis anticus tendon to the outer side of the foot, etc., have been tried, but with most disappointing results.

The "clubfoot boot and splint," presently to be described, is recommended as a palliative. Apart from this, re-education in a department for functional disorders is now the accepted line of treatment (see Appendix).

Contracting Scars may be a mechanical cause of inversion or may be associated with some functional spasm. There is in this case a definite lesion to be treated. The scar should be excised if possible, and the foot put up at once in the everted position of over-correction on a Clubfoot Shoe Splint (Fig. 29, p. 130). When the wound is healed plaster of Paris is applied for a month, after which time the patient may walk in the Clubfoot Boot and Splint (Fig. 34 A and B). The sole and heel of the boot are built up for one-third of an inch higher on their outer half. A side bar on the inner side of the leg is used, ending above in strap passing round the leg below the knee and turning in below to fit into a socket in the heel of the boot. A broad strap is fastened to the outer side of the boot and is buckled round the bar on the inner side. This arrangement when properly fitted holds the foot in the everted position. A chain, as shown in Fig. 34A, may sometimes be useful.

In cases where the scar cannot be excised, it should be gradually stretched on the shoe splint or successive

plasters until the everted position is reached. Continuous retention for three months is then necessary, after which the clubfoot boot may be used. In

FIG. 34A.—CLUBFOOT BOOT AND SPLINT.

other cases where stretching is not possible, the condition may have to be treated from the first like an inveterate clubfoot by tenotomy of the plaster fascia and invertors and wrenching of the foot into the everted position. The foot is put into plaster for

a month after healing, and then the clubfoot boot is applied.

Mal-united Fractures causing inversion of the foot.

FIG. 34B.—CLUBFOOT BOOT AND SPLINT.

There may be rotation deformity of union at any point in the shaft of the tibia. In this case a linear osteotomy should be performed near the site of the malunion. Osteotomy of the fibula may also be needed. The limb is then put up on the Skeleton Leg-Splint

(Fig. 30, p. 131) with after-treatment as in other cases of mal-union of the tibia.

If the inversion is caused by mal-union at the lower end of the tibia and fibula, the tibia and fibula should

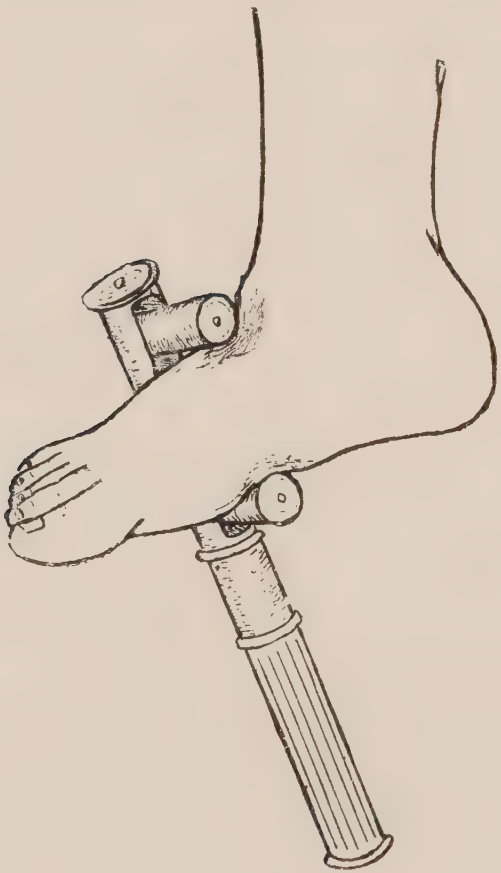

FIG. 35A.—WRENCHING FLATFOOT (TO INVERT).

be divided by linear osteotomy just above the ankle-joint. The correction may follow immediately, or if there has been previous prolonged suppuration it is better to wait for a week and then correct the deformity with the Thomas Wrench (shown in Fig. 35).

Plaster of Paris should be used for six weeks from healing, after which time the patient may walk in the clubfoot boot.

Wrenching for Varus Deformity.— The Thomas wrench is often used imperfectly and not to full advantage. The patient's foot should lie beyond the end of the operating table. In the case of varus the wrench should be applied to the inner side of the foot

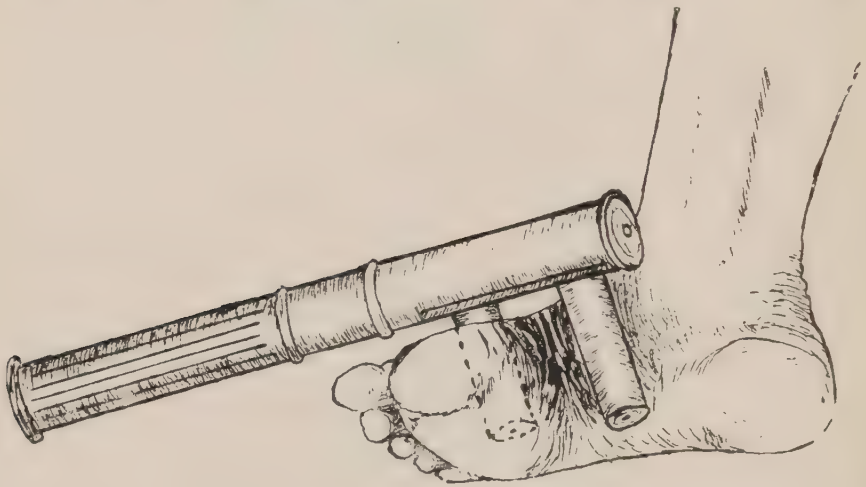

Fig. 35B.—Wrenching Flatfoot (to Adduct).

over lint, as near the ankle as possible, and screwed very tight. The handle should lie beyond the foot. The surgeon, standing on the inner side of the foot, steadies the ankle with one hand, while he grasps the foot and the wrench with the other to aid the wrench and prevent its slipping. He should actuate the wrench by bearing the weight of his body against the handle, while he everts the foot at the same time with his hands. A great deal more force can be applied by this method than by holding the handle

of the wrench in the hand. It is, moreover, safer, as less muscular effort is required and the movements are consequently under better control.

Everted Foot : Valgus : Flat Foot.—The causes of this deformity are exactly similar to those causing inversion, but acting on the opposite side of the limb. Thus, there may be damage of muscles or their nerves on the inner side, or spasm or scar contractions on the outer side. These do not need any separate discussion, except to say that since eversion spasm is almost entirely a question of the peronei, it may be relieved easily by tenotomy of the peronei and the use of the boot presently to be described.

Mal-united fractures causing eversion of the foot are of great importance and need special consideration. A flat everted foot is a weak foot, and interferes very much with the function of the limb. Reference has already been made to this condition under mal-union of the tibia, but the type here to be discussed is complicated by injury or displacement of the ankle-joint, and is allied to the Pott's fracture arising from other causes. A deformity of this kind is frequently seen following a gunshot wound at or near the ankle-joint with prolonged suppuration, perhaps leading to difficulties in gaining and maintaining a good position during the early stages, or from the yielding of weak bone after an early good position. In this class of case there is usually a fracture of both malleoli, with eversion of the foot and a stiff plantar flexed ankle-joint. As in Pott's fracture, there will probably be some backward

displacement of the foot. Weight-bearing is painful, and the patient walks dragging the affected foot, which is pointed outward.

Treatment is on the same lines as that of an old Pott's fracture. It is a mistake to attempt to restore the parts to their former anatomical relations by opening up the mal-union. Far better results can be obtained by restoring good alignment through attacking healthy bone just above the lesion.

Operation.—The tibia is exposed at its lower end by a vertical incision on the inner side. Periosteum is stripped backwards and forwards. A wedge of bone is then taken from the tibia with its base to the surface, and rather wider in front than behind. This is to provide for inversion and dorsiflexion of the foot. It is important to be sure that the wedge extends completely from front to back of the bone; in depth it should extend nearly out to the tibio-fibular joint. An osteotomy of the lower end of the fibula is also necessary. The author recommends making this from the same wound by driving an osteotome straight through the depth of the wedge in the tibia until the fibula is divided. With slight leverage action of the osteotome, combined with twisting inwards of the foot, the reduction of deformity can be quickly and easily made. An alternative method is to make the division of the fibula through a separate incision, to close the wounds and to leave the actual reduction of the deformity until a fortnight later. It may be found, however, in the absence of previous experience of the method, that the subsequent reduction

cannot be made thoroughly, possibly owing to some fault of technique in the osteotomy. The immediate correction as described has proved satisfactory, and reduces the trauma of the neighbouring infected parts to a minimum.

Needless to say, perhaps, the operation should be done only under the severest asepsis, with protection

FIG. 36A.—MOULDED SPLINT FOR FLATFOOT.

of the foot and the skin surrounding the wound with sterilised towels.

No retaining screws or nails are needed. The foot is put up in any splint which ensures good inversion and a right-angled position of the foot. A long gutter splint previously moulded is useful. It is well padded throughout and then placed on the outer side of the leg and wrapped round the foot as far as the inner

malleolus. Bands of adhesive plaster will retain it and the foot in the right position (Fig. 36).

When the wound is healed the foot and leg are put in plaster of Paris for six weeks, care being taken that the corrected position is maintained. After that interval the patient may walk in a Flatfoot Boot

Fig. 36B.—Moulded Splint for Flatfoot.

and Splint (Fig. 37, p. 153). The sole and heel of the boot are raised one-third of an inch on their inner side. The heel is also advanced or crooked on the inner side. An iron side bar is fixed on the outer side. This ends above in a leather band round the leg below the knee, and at its lower end is turned inward at right angles to fit into a socket in the heel

of the boot. A broad leather strap is fitted to the inner side of the boot. This ends above in two narrower portions which pass round the ankle to be buckled at the outer side of the side bar to aid in

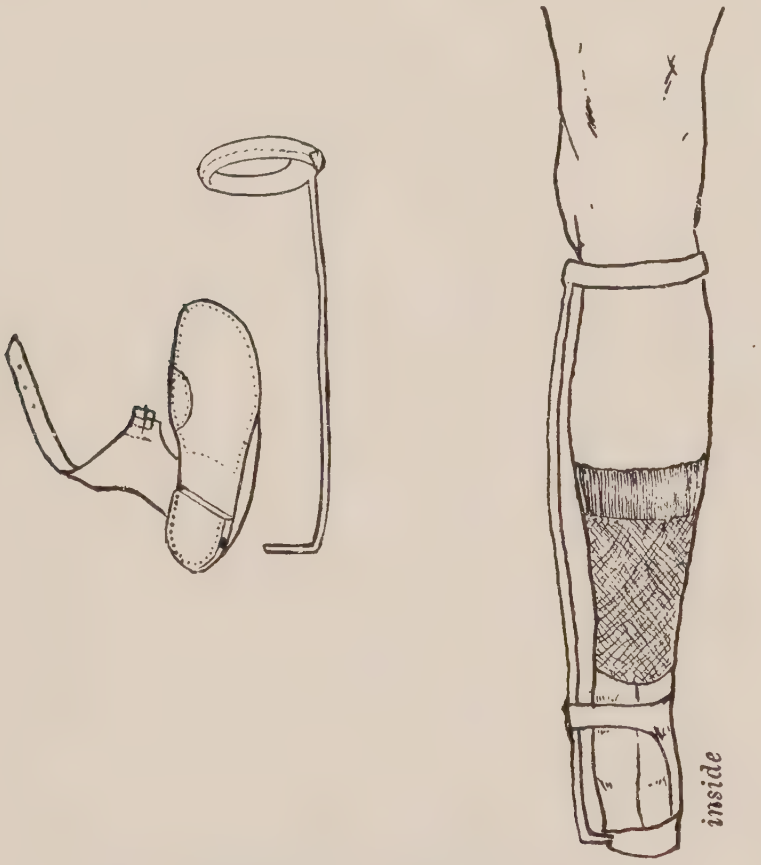

Fig. 37.—Flatfoot Boot and Splint.

keeping the foot inverted. The apparatus should be worn for at least six months.

Flatfoot may also arise from wounds of the tarsus. Even if union has taken place in a good position, subsequent walking while consolidation is imperfect

may lead to yielding of the longitudinal arch of the foot with pain or deformity. Forcible correction with the Thomas wrench will probably be needed. (The method of application is shown in Fig. 35, pp. 147, 148.) This should not be done until wounds are well healed and all inflammation has subsided for three months. The foot must be over corrected and fixed in the inverted position in plaster of Paris for six weeks, after which the flat-foot boot and iron may be worn. A wedge-shaped tarsectomy in front of the inner malleolus may rarely be needed. The author has not had occasion to make use of this procedure.

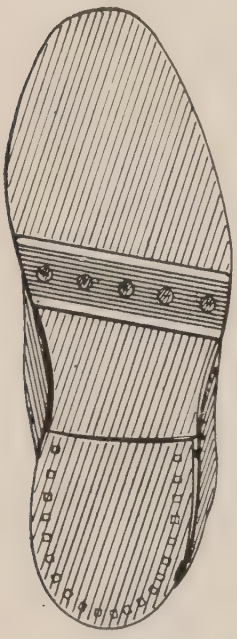

FIG. 38.—"FOOTBALL BAR."

Metatarsalgia. — This may occur after wounds of the foot, as a symptom and not as a definite disease. The use of the Football Bar (Fig. 38) will often prove of great assistance in troubles in the fore part of the foot, as it takes the weight off the heads of the metatarsals and allows the patient to walk with the fore part of the foot comparatively in a state of rest. In some cases it is advisable to excise the head of the fourth metatarsal bone through a dorsal incision, as in similar conditions of civil practice.

INJURIES OF PERIPHERAL NERVES

Interference with the functions of the peripheral nerves is among the common results of gunshot injuries. The lesion is manifested by—

(*a*) Faulty attitude of the limb from paralysis of certain muscle groups with loss of balance at joints due to gravity or tonic contraction of unaffected opposing muscles.

(*b*) Loss of certain powers of movement from paralysis of motor function in the muscles supplied by the affected nerve.

(*c*) Trophic changes, manifesting themselves in a short time by wasting of muscles and cessation of the normal process of desquamation, so that the skin area affected becomes dry and scaly, with heaped-up epithelium, and at a later date by thin glossy skin, long curved nails and possibly "trophic ulcers."

(*d*) Circulatory changes. There may, of course, be a concomitant injury of the artery supplying the part, as nerves and blood-vessels usually lie in close proximity; or there may be interference with blood supply from scar tissue round the vessels; but apart from this the paralysed part is cold and blue, both from deficient movement and apparently from loss of normal vasomotor control from injury of vasomotor fibres running in the nerve.

(*e*) Defective sensation in the area supplied by the divided nerve. Finer sensation to light touch and to small changes of temperature, and the subjective power of localisation of stronger stimuli, is lost over the whole of the area anatomically supplied by the nerve in question. This is called "epicritic" sensibility. Loss of sensation to painful stimuli, such as pinprick and extremes of heat or cold, is confined to a smaller area within that of loss of finer sensation. This is known as "protopathic" sensibility.

Loss of sense of deep pressure and of passive movement of joints over a still smaller area. This sensation, known as deep sensibility, is carried by nerves along the blood-vessels, tendons and bones, and is not lost unless the lesion is at some distance from the periphery, or the tendons themselves are divided.

(*f*) Changes in the reaction to electrical stimuli. They are of the following kinds—

1. *Faradic.* The affected muscles fail to contract to stimuli from the faradic or rapidly interrupted current. A healthy nerve-muscle will respond to these stimuli.

2. *Galvanic.* The response to stimuli at make and break of a constant current will be sluggish and peristaltic in its nature and not brisk, as in the case of healthy muscles. There are also what are called polar changes, that is, that with the kathode at the affected part and the anode on an indifferent part of the body, the contraction on making or closing the circuit will be smaller than if the current is in the opposite direction with the anode over the affected

part (A.C.C.>K.C.C.). In the normal condition the reverse is the case, and the Kathodal Closing Contraction is greater than the Anodal Closing Contraction (K.C.C.>A.C.C.).

The whole of these phenomena constitute what is termed the Reaction of Degeneration. The polar changes are chiefly of academic interest, and from the clinical standpoint the important features of Reaction of Degeneration (R.D.) are—

1. Loss of reaction to Faradism.

2. Sluggish, peristaltic, or vermicular contraction to Galvanism. A typical case of complete division of the ulnar nerve in the upper arm, say six months after the injury, may be taken to illustrate the various symptoms.

(*a*) *Attitude.* Owing to paralysis of the interossei and uncontrolled action of the opposing muscles, the fingers will be held hyper-extended at the metacarpo-phalangeal joints and semiflexed at the inter-phalangeal joints. The condition is most marked in the inner two digits, where the lumbricals are also paralysed (Fig. 39, p. 158).

(*b*) *Paralysis.* The flexor carpi ulnaris being paralysed, there will be weakened flexion of the wrist with slight deviation to the radial side.

There will be imperfect flexion of the two inner fingers from paralysis of the corresponding part of the flexor profundus digitorum.

The fingers cannot be separated and brought together owing to interossei and abductor minimi digiti paralysis.

(*c*) *Trophic Changes.* There will be wasting of the inner side of the forearm, of the hypothenar eminence, and in the interosseous spaces.

FIG. 39.—LEFT ULNAR PALSY.
[From *Nerve Injuries* (Purves Stewart and Evans).]

The surface of the inner two fingers will be dry, cold, blue, and scaly, and the nails will be long and curved. The outer side of the ring finger supplied by the median will be less affected. A corresponding

region of the front and back of the hand will be likewise affected.

There may be trophic ulcers on the little finger or on the inner side of the hand.

It should be noted that these changes vary in degree and according to the duration of the injury. Sometimes they are but little marked.

(*d*) *Circulatory*. The affected part may be blue and cold to the touch.

(*e*) *Sensation*. There will be loss of epicritic sensibility over the anatomical supply of the nerve, viz. the inner one and a half fingers and a corresponding area of the front and back of the hand. Protopathic sensibility, or sensation of extremes of temperatures, and pinprick, will be lost over the little finger and a small portion of the hand above it. Sense of deep pressure will be lost in a part of the little finger only.

(*f*) *Electrical Changes*. There will be loss of response to faradism and sluggish reaction to galvanism in all the affected muscles. Here also it should be noted that the conditions vary with the duration of the injury, with the temperature of the limb, and with the degree to which massage and other treatment have prevented malnutrition.

The Nature of Nerve Injuries.

Clinically a nerve injury presents itself in one of two forms—

(*a*) An **incomplete** interference with the function of the nerve, as indicated by paralysis of some of the muscles supplied by it, with or without an impair-

ment of sensation of a subtotal degree, or by pain and hyper-æsthesia, as in the condition of causalgia, to be described later.

(*b*) A **complete** suspension of the function of the nerve.

In the former case it is obvious that the nerve has not been totally divided anatomically; in the latter it remains to be seen whether there is, or is not, anatomical loss of continuity. The loss of function may be due to pressure only, to division of some fibres with pressure on the intact fibres, or to total anatomical division of all fibres.

It is, therefore, essential to separate in one's mind the following two aspects of the case—

1. The **clinical** aspect: as to whether there is complete or incomplete suspension of function.

2. The **pathological** aspect: as to whether all, some, or none of the nerve fibres are actually cut across.

Experience has shown that in the majority of cases there is not a gross lesion of the nerve itself, because a large proportion of cases of nerve palsies resulting from gunshot wounds recover without operation, and a further proportion of cases operated upon show no actual division of nerve fibres. The projectile in its passage may bruise the nerve directly or indirectly, the subsequent hæmorrhage or suppuration may lead to the formation of dense scar tissue, the foreign body may actually lie in contact with the nerve pressing upon it, or a fracture may cause pressure on the nerve, either immediately or in the course of union by callus formation.

When there is actual division of fibres the lesion usually conforms to one of the following types—

(*a*) The nerve may be partially cut across, with the subsequent formation of a mass of newly formed tissue on the affected aspect, consisting of fibrous tissue containing some nerve fibres which grow downwards from the central end in an attempt at repair—a Lateral Neuroma. The palsy itself may be complete as a result of bruising of the undivided fibres, or of pressure upon them by contraction of scar tissue.

(*b*) The nerve may have been pierced by the projectile, which has severed some of its fibres, and a regular olivary swelling may be formed as the result of scar tissue and the down-growth of new nerve fibres from above—a Central Neuroma. The paralysis will usually be complete.

(*c*) The nerve may be totally divided. The divided ends may unite in a mass of scar and nervous tissue, or there may be a definite gap. In the latter case each cut end, unless buried in callus, will form a bulbous termination. The upper bulb—a Terminal Neuroma—consists of a mass of down-growing nerve fibres in a fibrous tissue scaffolding. The lower bulb is merely a fibrous cap over the end of the nerve. These bulbs may be quite distinct or may be joined by a strand of scar tissue. The paralysis is, of course, total.

Treatment of Nerve Injuries.—Primary suture is always desirable when practicable. This may include suture in the immediate treatment of the wound, or

joining the cut nerve when in sight at the time of secondary suture of the wound.

Cases seen at orthopædic centres have long passed this stage. The wound may be completely healed and the nerve palsy definitely developed.

At this point the future treatment may be divided into three phases—

1. The immediate, or pre-operative.
2. The operative.
3. The post-operative.

The immediate concerns are the prevention and correction of deformity, the maintenance of nutrition and function of the affected limb, and the establishment of an accurate diagnosis and prognosis.

Adequate Splinting to obtain relaxation of the paralysed muscles and to overcome contractures is of the first importance. The methods are to be described in connection with the lesions of individual nerves.

A paralysed muscle has the very poorest chance of recovery so long as its fibres are allowed to be stretched. They must be put into a position of relaxation and *kept there.* All the time the paralysed muscle fibres are on the stretch, they are suffering damage which sooner or later will be past remedy. As will be seen, all varieties of nerve palsy do not lend themselves to splinting in relaxation, but this principle must be applied as thoroughly as possible. The same method of splinting which relaxes the paralysed muscles will also serve to overcome the unbalanced action of the opposing groups. In neglected cases the opposing muscles may become shortened to a very

troublesome degree, and this should never be allowed to occur.

Maintenance of Nutrition and Function in the affected limb is the next consideration. Apart from the actual trophic changes due directly to the paralysis, the whole limb tends to be used less than usual, circulation is impaired, and the limb does not get its normal amount of exercise, so that its nutrition becomes generally interfered with, muscles become wasted, tendons, ligaments, and joints stiffened.

The means employed include the following—

(1) **Warmth.**—A paralysed part is cold. The limb should, therefore, be well protected by glove, woollen sleeve, cotton-wool casing, etc. Part of the daily round of treatment may consist of soaking the limb in warm water or a whirlpool bath, or melted paraffin-wax bath. Care is needed to see that the insensitive parts are not exposed to too high a temperature, or trophic burns may result and prove very troublesome.

(2) **Massage.**—This will do a great deal to improve the circulation and muscle nutrition. It should be applied daily not only to the paralysed muscles, but to all those of the limb. The masseuse should always be specially instructed in the treatment of the paralysed muscles, and emphasis should be laid on the importance of not allowing the paralysed muscles to become stretched. The splint should be removed only under supervision, if at all, and the part must be maintained in the prescribed position by other means while the splint is off. For example, in the case of musculo-spiral palsy, the forearm and hand may be

held with the flexor surfaces upward, while the splint is being removed. Gravity will then maintain the correct position as long as necessary. When the hand has to be turned palm downward, the masseuse will hold the wrist and fingers in the dorsiflexed position with her own hands, or by placing the patient's hand and wrist on a suitable support.

(3) **Passive Movements.**—So far as is strictly consistent with the principle of keeping paralysed muscles relaxed, all the joints of the limb must daily be put through their full range of movement. On no account must paralysed muscles be stretched in order to carry this out. As will be seen, in the case of median or ulnar palsy, relaxation by splinting is not generally practicable, and the joints of the wrist and fingers may be put through their full range at each session of treatment. Moreover, use of the hand is advisable in these cases. If, however, there is a tendency to contracture splinting may be needed, perhaps constantly or perhaps only at night, with free use of the hand during the day. In musculo-spiral cases relaxation must be without a break of any kind. Stiffness of the wrist in dorsiflexion is not a contingency which need cause anxiety. Stiffness of the metacarpo-phalangeal joints in hyper-extension may prove very troublesome, and is to be avoided by not letting these joints become hyper-extended. The splint recommended (Fig. 12, p. 66) will prevent this and also hyper-extension of the inter-phalangeal joints. The utmost degree of passive movements allowable in musculo-spiral palsy is as follows: The

forearm and hand may be allowed to lie flat on the table under supervision of the masseuse, that is to say, flexion must not go beyond a neutral or straight position of the wrist. As regards the fingers, they may be allowed to drop into the semiflexed position **only while the wrist is kept hyper-extended by the surgeon or masseuse.** This limit of movement must be strictly adhered to. It is far better to forbid passive movements altogether than to allow more than this, as joint stiffness in musculo-spiral palsy is never severe with proper splinting. The plan of having a short wrist splint which does not support the fingers is one often followed, but it is not recommended, as it does not maintain enough relaxation of the extensor communis digitorum. In paralysis of the sciatic and its branches no passive movements are to be allowed except of the toe-joints. The splints recommended will allow quite enough play of the ankle to prevent stiffness.

(4) **Electricity.**—Appropriate stimulation of the paralysed muscles will cause them to contract and tend to oppose atrophy. It will also aid in improving the circulation, acting as a sort of internal massage. Care should be taken that healthy muscles are not stimulated to contract, especially those opposing the paralysed groups. For this reason electric baths are to be avoided in most cases. It is not believed that electrical stimulation has any effect in aiding nerve regeneration directly.

Splinting and attention to nutrition as indicated are, therefore, to be adopted as a routine measure in practically every case.

If the wound is incompletely healed, massage is deferred, but electrical stimulation may be started.

The treatment is carried on through a period of probation, during which neurological examinations are made from time to time to observe and record progress. Operation is to be deferred in the presence of—

(*a*) Suppuration or sinuses.

(*b*) A faradic reaction, in all or some of the muscles supplied by the nerve under consideration, in which case there is good prospect of recovery without operation.

(*c*) Improvement either of a complete or incomplete lesion, so long as the improvement is progressive. An improvement in the electrical reactions alone is considered as a signal for delay.

Operation may be assumed to be indicated in the following conditions—

(*a*) When wounds are soundly healed for one month in simple cases, or for three months when there has been suppuration.

(*b*) When there are signs of complete division which do not become altered within three months of the first observation. Absence of faradic reaction with sluggish contraction to galvanism are fairly sure signs of a grave lesion. While the presence of a faradic reaction indicates a mild injury, the absence of the faradic reaction by itself is by no means a sure indication of a grave injury, as the reaction may be absent in the actual presence of active motor-power, or may vary with the temperature of the atmosphere

or the limb. The significance of its absence must be interpreted in conjunction with the nature of the galvanic reaction, sluggish or brisk.

(*c*) When an incomplete lesion shows either retrogression or an absence of progress over a period of two months.

(*d*) When severe burning pain (causalgia) is present.

These indications are general and not to be regarded as hard-and-fast rules. For example, one would be more inclined to cut down upon and suture the musculo-spiral than the median or ulnar, because the prognosis after suture is better in the case of the first-named than in the other two cases. Again, an incomplete lesion may be of so slight a character that it may be deemed inadvisable to interfere at all.

Further, the case may be complicated by some condition of bones, joints, or muscles which would modify a decision. While it is well to do everything possible to improve the conditions of muscles and joints before operation, it does not seem wise to defer the latter on account of mere stiffness or contracture, for the process of general treatment can be continued just as well in most cases after operation as before, and meanwhile it may be hoped that regeneration is going on.

Operative Treatment.—Wounds which have once suppurated, as nearly all war wounds have, are very ready to suppurate again on the slightest provocation, even if healing has been complete for months or years. Masses of granulation tissue or even small collections of pus containing micro-organisms become shut off

by contracting scar tissue and lie quiescent indefinitely. This is especially the case where there has been callus formation after fracture. A further operation may lay open any such potential focus of suppuration. If trauma is small in the operation and if no more germs are allowed to enter the wound, all may go well and primary union may be obtained. But a degree of inflammation which would not perhaps matter in previously healthy tissues may be enough to stir the latent germs into activity, and fresh suppuration may arise worse even then than after the original wound. In such circumstances nerve suture is doomed to failure, and possibly such a failure as to spoil any future chances of success. It follows, therefore, that the aseptic technique must be of the most rigid description. Caps and masks must be worn; gloves must be put on without their outer surfaces being touched by the bare hand, even when thoroughly prepared; the skin knife must be laid aside after the primary incision and the deeper dissection made with a fresh knife. As soon as the skin incision is made, fresh sterile towels must be clipped to the edges of the wound to shut off the skin entirely from the open wound. During the operation a torn or pricked glove must be changed at once, as the fluid between the hand and the glove soon becomes germ infected from the operator's skin. The whole procedure must be marked by the utmost gentleness to avoid undue trauma of soft parts. The introduction of the hands into the wound must be reduced to the minimum compatible with efficiency.

It must be looked upon as a risk only to be taken under compulsion.

Perfect hæmostasis is of great importance. A collection of blood round the line of nerve suture will interfere with its nutrition and is very liable to break down in suppuration. Owing to the large amount of young scar tissue to be opened up there is often a good deal of oozing. This is chiefly controlled by pressure and hot swabs. In view of the undesirability of recurrent oozing the use of the tourniquet is to be avoided. When oozing is present at the end of an operation, a drainage tube should be used for twenty-four hours.

It is generally desirable to avoid cutting through the former scar in making the incision. A gently curved flap, with its centre intersected by the line of entry and exit wounds, will usually meet the needs of the case. With all the precautions referred to above, the exposure of the nerve is proceeded with. The methods of approach in the different nerves are described later. It is rarely necessary to cut through muscle fibres. Muscle bellies can usually be separated and the nerve exposed on the same lines as are given for the exposure and ligature of accompanying arteries. The nerve must be brought to view by pulling aside neighbouring structures, and not by pulling the nerve from among them. It must never be touched or held, much less pinched, with forceps. This of itself is enough to cause a nerve lesion if one had not already been present. The most useful method is to display healthy nerve above and below

the suspected site of injury and to work towards the lesion.

As already indicated, a variety of conditions may be found. The case of complete anatomical division will be considered first, and the technique of nerve suture described.

Operation for Suture of a Completely Divided Nerve.—Healthy nerve having been exposed above and below, and traced towards the injury, a mass of scar tissue will usually be found, with the cut ends of the nerve embedded in it. The ends of the nerve in the scar will be indicated by slight local thickening of the lower end, which is covered with a cap of fibrous tissue and a definite bulb at the upper end—a terminal neuroma—where the cut fibres have grown downwards in an attempt at recovery and have been met and surrounded by scar tissue. Working towards the scar it is sometimes possible and always desirable to excise the whole mass of scar tissue still in continuity with the two divided ends of the nerve. This must be done by attacking the scar itself and in no circumstances pulling on the healthy portions of nerve. If it is obvious that no nerve tissue runs through the scar the latter is now divided at its middle, the two portions still being left attached to the divided nerve ends. As this is the class of case, above all, in which difficulty of approximation may occur, the nerve should now be sufficiently stretched. A pair of forceps is clamped on to each portion of scar, the forceps are crossed over each other, and traction is made in the long axis of the nerve. In most cases

it will be found that healthy portions of nerve can be brought to meet in this way. If not, the neighbouring joints should be flexed, which will help considerably. Supposing that approximation without tension is still seen to be impossible, something more drastic must be done. At this stage, but not before, the nerve must be handled, with a view to dislocating it from its bed. While keeping up the tension on one of the ends by pulling on the forceps, which are still attached to the intermediate scar, the gloved finger is passed under the nerve and along its course for some inches. It will be found that a considerable further length is gained. Approximation in difficult cases is nearly always possible by applying this manœuvre to both portions of nerve. Cases where union is still impossible are discussed later.

It having been ascertained that approximation is possible, the level for suture is determined. This is done by keeping each portion tense, pulling in the long axis by means of the forceps still grasping the scar, while a transverse cut is made two-thirds through the nerve at the nearest point at which it is thought to be healthy. The cut surface is examined for the presence of nerve bundles. These may be seen as grey, succulent-looking points bulging slightly from the cut surface. It is essential that these should be seen at the level of suture. Further cuts must be made until these are visible. In simple cases where approximation is easy it is well to cut away freely to be sure of getting to healthy nerve.

The question of the treatment of the upper end

bulb (the terminal neuroma) is not altogether a simple one. The usual practice is to resect it entirely and to join portions of about equal size when it can be done without undue tension. Where serious tension is threatened part of the upper bulb showing nerve bundles may be retained and sutured to the lower portion of nerve. This does not seem to impair the result; in fact, some cases in which part of the upper bulb has been retained have shown very good and early recovery. It may be that the newly formed fibres in the bulb have actually high powers of down-growth, and it is the author's opinion that it is never bad practice to leave a part of the upper bulb, but the retained portion should be small to approximate as nearly as possible in size to the distal portion, and it is essential that nerve bundles should be clearly seen in the cross section.

The level for suture having been determined, the ends are brought together by pulling in the forceps. The scar is not fully detached until the first few stitches are passed. Various methods of suture have been recommended. The author is opposed to any stitches through the nerve and uses a fine continuous stitch, bringing the edges of the nerve sheath together all round. This ensures good approximation and prevents the outgrowth of nerve fibres between the stitches. Before the first stitch is passes it is most important to be sure that there is no axial rotation of either portion of nerve, so as to ensure as far as possible that corresponding fibres are brought end to end. A fine cutting needle of the Lane's cleft

palate type is used, threaded with catgut, size O to 6/O, according to the size of the nerve. The first stitch is passed and tied, leaving a free end long enough for tying again at the end of the round of stitches. A clip is placed on this end and it is held by an assistant. The circular suture of the nerve-sheath is then proceeded with. After three or four stitches have been made the remaining third of the nerve, previously left in continuity with the part to be removed and the scar, is cut through, and the scar, etc., is removed. The stitch is continued without handling the nerve by holding on to the suture gut after each stitch is pulled tight to steady the nerve for the next of the stitches. The procedure is very much like that of suturing intestine with a continuous stitch. Pulling the stitch tight makes the part for the succeeding stitch present itself ready for the needle to be passed. When the starting-point is reached again, the end of the catgut which has been carried round the edge is tied to the free end left at the beginning just as with the continuous intestinal suture.

The suture completed, the question arises as to where the sewn nerve shall lie. Healthy soft parts are undoubtedly the best bed for the nerve. The nerve may be allowed to lie between two uninjured muscles, or a neighbouring muscle may be gently split a little in the line of its fibres and the sutured part laid in the cleft thus made. A bed of scar tissue or of a raw surface are to be avoided in any way possible. The total excision of the scar which has

been advised where practicable will often exclude the former of these, but sometimes it will be found inevitable that the nerve must lie on scar tissue. In these circumstances only it is advised that the suture line shall be wrapped round before being placed on the scar. A thin layer of normal fat may be dissected off from the subcutaneous tissues exposed, or a sheet of cargile membrane (dry sterilised peritoneum) may be used after being dipped in sterilised vaseline. The routine use of such wrappings is deprecated, as they may of themselves cause formation of scar where they are placed.

In closing the wound every effort should be made to let the nerve be covered as far as possible with soft parts, so that it shall not lie beneath an unsatisfactory covering of scarred skin only. Above all, it should not lie directly under the line of skin suture. The flap incision can usually be made to prevent this contingency.

Impossibility of Approximation.—It has been already stated that in nearly every case the ends can be brought together by stretching the nerve in its long axis, by flexion of joints, and in more difficult cases by some dislocation of the nerve from its bed. This last measure is in itself undesirable if it can be avoided, but it is far better than leaving the nerve unsutured or than any of the more desperate remedies now to be discussed. It is only in rare cases that the above measures will fail if properly applied —in three per cent. of cases in the author's experience.

In the instances where these devices fail, a variety of measures have been suggested and practised—

(1) **Shortening of Bone.** — This is particularly applicable in the case of long gaps in important nerves near the elbow-joint. A portion of the humerus is removed of sufficient length to bring the cut ends of the nerve together. The method is described in connection with the nerves of the upper limb.

(2) **Tendon Grafting.**—This procedure is especially valuable where there is no nerve to suture, as in the case of damage of the posterior interosseous nerve below the supinator brevis, where it has rapidly broken up into its important terminal branches. Speaking generally, it should be reserved for such cases, or for long-standing nerve palsies where nerve suture has failed.

(3) **Nerve Grafting.**—A portion of an unimportant healthy nerve is cut clean out, and inserted into the gap, its ends being sewn end to end to those of the nerve which it is desired to reconstitute. This is, as a rule, the course to be adopted. The results are still under judgment, but some recovery has been seen, and it is decidedly better than doing nothing.

(4) **Bridging with Foreign Material.**—The edges of the sheath above and below may be joined by a number of strands of catgut, and the junction wrapped round with cargile membrane. The prospect of successful result appears on the face of it to be a very poor one, and much less promising even than that of a nerve graft. It may perhaps be justifiable when

the gap between the cut ends can be reduced to half an inch or less.

(5) **Nerve Anastomosis.**—The peripheral end of the divided nerve is sewn to the central end of a neighbouring healthy nerve which has been divided for the purpose. This is useful only in the case of hypoglosso-facial anastomosis for facial palsy. The original function of the borrowed nerve is lost entirely, and it is difficult to imagine any condition in the limbs where the procedure would be indicated.

A more outwardly attractive proposition is to divide the healthy nerve only partially, leaving it in anatomical continuity, and using the flap or split-off portion to join to the peripheral end of the damaged nerve. It is, however, a thoroughly bad procedure in any part below the clavicle. It is often stated on apparently good authority that a third of a nerve may be divided without interference with function, owing to the fact that the fibres of the nerve are not yet specialised into the individual branches, but run at haphazard.

The premises and conclusion are alike untrue, of most nerves at least, and certainly of any of those of the limbs below the plexuses. The only situation to which the statement might apply is to such as the region of the roots and trunks of the brachial plexus above the clavicle. In this position it is advised later to join the peripheral end of the upper nerve root or trunk to part of the next root or trunk in the event of direct restoration being impossible. Here the nerves are certainly less specialised, and the

hazarding of part of the function of a lower trunk is worth while in a hope to restore the very important upper trunk or root.

Below the clavicle the method is nowhere applicable. It is totally unsound to prejudice the function of a healthy peripheral nerve for the sake of a doubtful benefit to a damaged nerve, and therefore all nerve anastomoses in this region, *i. e.* below the clavicle, are to be condemned very strongly. Results have been disastrous.

It will be seen, therefore, that the insertion of a graft removed from an unimportant nerve is in most cases the method to be employed when direct union is impossible.

Partial Division and Doubtful Conditions.— An obvious and straightforward case of complete division as described above, needs little judgment. It is merely a case of operative technique. In many instances, however, the conditions found are not so simple, and great care and some experience are required in deciding what shall be done with the nerve lesion found.

The local condition found may be one of the following—

(*a*) The nerve may be found in continuity, but with a regular bulbous swelling upon it. This feels hard and clearly contains much fibrous tissue. It may have been due to a piercing of the nerve with the formation of a central neuroma and scar without complete division of the nerve fibres, or it may represent Nature's attempt at recovery by a coarse union

of a completely divided nerve by a relatively small amount of fibrous tissue. If the case has been carefully chosen on clinical grounds with unimproved total loss of function over a reasonable period of probation, and with a sluggish reaction to galvanism, then it is recommended to excise the node and perform end-to-end suture. The prognosis of a clean end-to-end suture is good. That of leaving such a case alone is at least doubtful. If, however, the lesion is clinically only a partial one and without symptoms of Causalgia (*q.v.*) it may be carefully dissected to see if a part of the nerve can be identified as in continuity. It is recommended in any case to shave off the enlargement before its resection. If any part of the nerve can be traced through the swelling it is to be preserved. If not, it is probably better to sacrifice a few fibres for the sake of the whole nerve.

(*b*) The nerve may be found in continuity with a lateral swelling. In this case it is almost certain that part of the nerve is intact. Any rough fibrous tissue is dissected off the surface when one may expect to find by dissection that the division of fibres is on one side only. The divided fibres must be dissected off from the side of those which are intact; the former are treated as a divided nerve by trimming and end-to-end suture, the latter are allowed to remain as a sort of loop by the side of the sutured portion.

(*c*) The nerve may appear to be in continuity when dissected from scar tissue, but the condition of the scarred portion is bad, with roughened surface and

thinned portions, as though it had been nibbled into. If any one part can be identified as sound it should be preserved. The remainder should be resected with end-to-end suture of healthy looking nerve. Such cases do very badly under conservative treatment, as might be imagined.

(*d*) The nerve may be undivided and merely bound down by scar tissue. When the latter is removed, the nerve may be found to be shrunken, but with its sheath more or less intact. In this case continuity should be carefully preserved and a fresh healthy bed found in which to place the nerve.

The Faradic Test at Operation.—The above types of injury are fairly distinct, and the line of treatment in each case may be laid down somewhat definitely. There remain, however, a large number of cases which lie somewhere between these extremes, particularly in the instance of scarring of the nerve.

In such circumstances the use of a weak faradic current applied directly to the nerve above and below the site of injury may sometimes be extremely useful. Special electrodes with long connections which can be sterilised are attached to the battery and are used by the surgeon during the course of the operation. The nerve is gently lifted from its bed and the results of stimulation above and below the lesion are compared.

The fine probe electrode is applied directly to the nerve below the level of the lesion, and the current turned on. Any response in the muscles supplied by the nerve will indicate that their fibres are intact

and must be preserved. The nerve is then stimulated above the lesion. The difference between the results here and those of stimulation below the site of injury shows the extent of the block to conduction without actual division of fibres and degeneration.

If, therefore, results are good below and bad above only, the prognosis is good without resection, as degeneration is small. If both results are negative, total excision of the injured part is probably needed.

Post-operative Treatment.—It should be clearly borne in mind that nerve suture is merely an incident in a long course of treatment of a paralysed nerve. The after-treatment is, therefore, a continuation of the methods applied in all cases of nerve injury. They comprise—

Warmth.
Splinting for relaxation.
Massage.
Passive movements of the limb, and in suitable cases of the joints directly involved.
Electrical stimulation with appropriate current.
Active exercises of the limb as far as is consistent with splinting.
Periodic testing of motor and sensory functions, and of electrical reactions.

It is important that primary conditions and subsequent changes should be carefully charted, so that there is a continuous record of the progress of the case.

Recovery after Nerve Suture.—Restoration of func-

tion of sutured nerves is very variable both as to time of onset and degree of completeness. The nerve with the best suture prognosis is the musculo-spiral for several reasons.

1. Because it is mainly motor in function, hence central motor fibres are most likely to grow down into distal motor tracts. In a much-mixed nerve like the ulnar a large number of motor fibres may be joined to sensory ones with useless result.

2. Because its function is simple as regards the hand and wrist, namely, to excite one coarse movement, that of extension.

3. Because the paralysed muscles can be easily and completely relaxed by splinting.

It follows therefore that the more complex the movements required, the more difficulty there is in obtaining relaxation, and the more sensory and motor functions are mingled in any particular nerve, the slower and less complete will be its recovery.

Two statements are commonly made—

(1) That the time after division at which the suture is made is a very important factor.

(2) That time of recovery varies more or less with the distance of the lesion from the final distribution of the nerve.

Recent experiences have added enormously to our knowledge of the finer points of nerve surgery, and the results obtained, as shown below, do not altogether bear out these two statements.

The following cases were recently picked out at haphazard from among a large number. They are

all cases of complete division of continuity from gunshot wound with secondary suture.

Nerve divided.	Interval between Wound and Suture.	Time of Observation after Suture.
Great Sciatic.	8 months.	18 months. Power in flexors and extensors of ankle.
ditto.	8 do.	4 months. Deep sensation present. Improved electrical reactions.
ditto	4 do.	5 months. Brisk galvanic reaction.
ditto	4 do.	18 months. Power in flexors and extensors of ankle. Faradic reaction.
ditto	11 do.	7 months. No improvement.
External Popliteal.	10 do.	3 months. Sensation improved.
ditto	6 do.	2 months. Electrical improvement.
Median above elbow.	26 do.	3 months. Brisk galvanic reaction.
ditto	7 do.	4 months. Power in all muscles. Faradic reaction.
ditto	6 do.	13 months. All muscles working. No epicritic return.
ditto	10 do.	6 months. Improved electrical reaction.
Ulnar above elbow.	26 do.	3 months. Brisk galvanic reaction in forearm.
ditto	7 do.	4 months. All muscles acting except interossei. Faradic reaction.
ditto	6 do.	13 months. All muscles acting.
ditto	12 do.	3 months. Sensation returning.
ditto	8 do.	7 months. Good power in all muscles. Faradic response. Protopathic return nearly complete.
ditto	15 years.	4 months. Signs of returning function.
Ulnar in forearm.	8 months.	7 months. Protopathic return.
ditto	6 do.	6 months. No improvement.
ditto	7 do.	7 months. No improvement.
ditto	0 do.	6 months. No improvement.
ditto	10 do.	6 months. Abductor minimi digiti and adductor transversus acting. Epicritic loss only.
ditto	6 do.	4 months. Interossei acting. Sensory loss clearing.
ditto	10 do.	6 months. No improvement.
ditto	5 do.	7 months. No improvement.
ditto	8 do.	5 months. No improvement.
ditto	11 do.	4 months. Anæsthesia clearing up.
ditto	6 do.	9 months. No improvement.
ditto	4 do.	7 months. No improvement.
Musculo-Spiral.	4 do.	6 months. Complete motor recovery. 8 months. Sent to duty.
ditto	2 do.	10 months. Sent to duty.
ditto	20 do.	7 months. Electrical improvement.
ditto	4 do.	7 months. Sent to duty.
ditto	5 do.	11 months. Sent to duty.

These results are by no means final as regards the

majority of the cases quoted, but so far as the limited series goes it suggests several points.

(*a*) That musculo-spiral cases do very well, as is already agreed.

(*b*) That within limits the length of interval between division and suture does not seem to affect the result very much.

(*c*) That suture of the ulnar in the forearm gives slow recovery as a rule.

(*d*) That the distance of the lesion from the periphery does not affect the result so much as might be expected. It is suggested that the superiority of results of ulnar suture above the elbow is due to the better muscular bed in which the nerve can be laid.

(*e*) That 75 % of cases show signs of regeneration in an average of about seven months after suture, even with such a large proportion of ulnar cases included, and that 40 % of all cases show some return of motor power in an average of seven months, again including an undue proportion of ulnar cases.

Electrical improvement was noted from the second month onward, sensory changes commonly in the third or fourth month, and motor return sometimes as early as the fourth month. Very few cases except musculo-spirals had good function within the first year. Epicritic sensation was very slow in its return.

Lesions causing Partial Loss of Function : Causalgia. It has already been seen that total loss of function clinically may be due either to complete or incomplete anatomical division of the fibres of the nerve trunk.

Some lesions are partial from the clinical aspect

also, and denote, of course, only a partial division of the nerve fibres at most.

The symptoms found may represent an interference with function generally, or a complete paralysis of a part of the nerve from any of the causes already mentioned.

Complete reaction of degeneration is rare. Usually there is a brisk galvanic response. If, however, any muscles are cut off completely from the nerve they will show signs of the complete reaction by sluggish response to galvanism, which will indicate the need for operation.

Motor changes may be absent, or there may be complete loss of power.

Epicritic sensation is usually lost almost entirely.

Protopathic changes are of two types. There may be loss of this form of sensation, as in cases of complete palsy.

In the other type pain is a prominent symptom, with tenderness on touch. The burning character of the pain has led to the name of **Causalgia** being applied to the condition. The pain is often of the severest intensity and reduces the patient to a state of misery. It is felt throughout the limb, but by careful investigation can be localised as chiefly in the protopathic area of the nerve affected. There is hyperæsthesia to pin prick, and generally speaking the signs are just the reverse of those of complete division. The affected part is hot, red and swollen, the skin is shiny and sweats profusely. At a later stage the skin becomes glossy; there is atrophy of subcutaneous

tissue and muscles, with marked contractures and arthritic changes, and the development of blisters and ulcers.

The nails grow fast, become rounded over the ends of the fingers and longitudinally striated. Apart from treatment the condition goes on for a very long time, and the patient's existence may become a burden to him. The explanation of the condition is still obscure. When present it is always accompanied by a partial nerve lesion, never by a complete division. It may be due to a neuritis of the nerve trunk itself, or to secondary vaso-motor changes in the sympathetic fibres surrounding the main artery of the limb. It is significant that the condition is chiefly associated with lesions of the median in the upper limb and the sciatic in the lower, both of which nerves have a named artery running in intimate relation with them.

Palliative treatment is unsatisfactory. The patient will often obtain some relief by wrapping the affected part in cold wet cloths.

X-ray applications have sometimes been used with some success.

Injections of 1 c.cm. of absolute alcohol into the nerve above its damaged region have brought relief from the pain on occasions. The results are often disappointing.

Stripping the sheath of the main artery of the limb to excise the sympathetic nerve plexus at one level has been done on occasions with complete cure of the causalgic symptoms.

If this procedure is unsuccessful or impracticable,

it is recommended to resect if possible the whole affected region of the nerve, and to make an end to end suture of apparently healthy parts. There may be other indications with respect to the function of the nerve which would make complete resection and end-to-end suture doubly desirable.

Treatment of Individual Lesions

It would require a large monograph to describe in detail the various symptoms, motor, sensory, trophic, etc., connected with lesions complete or incomplete, of the different peripheral nerves. For such, reference should be made to works dealing exclusively with the subject. It will suffice here to make such brief reference to symptoms as are necessary for the sake of clearness, and to turn attention rather to the aspect of surgical treatment of the commoner injuries.

Paralyses of the Upper Limb.

The Brachial Plexus.—It is necessary to have a mental or actual picture of this plexus at command in considering its lesions (Fig. 40, p. 188). It should be remembered that its five component **roots** from the fifth cervical to the first dorsal blend into three **trunks** as they appear in the neck, namely—

An *Upper Trunk* made up of the fifth and sixth roots.

A *Middle Trunk* formed from the seventh root.

A *Lower Trunk* composed of the eighth cervical and first dorsal roots.

In gunshot wounds above the clavicle any or all

of these three trunks are the most likely nerves to be damaged, as they are longer than the roots from which they spring.

When they have reached the axilla these three trunks have divided and blended to form three **cords**—

An *Outer Cord* formed from the upper and middle trunks.

An *Inner Cord* formed from the lower trunk.

A *Posterior Cord* formed from all three trunks.

In wounds below the clavicle, therefore, there may be a lesion of one or more of these cords or the nerves which spring from them.

A lesion of the intermediate divisions behind the clavicle might be complicated, and not such as could be included in a short description, so one may conclude to sum up—

(*a*) A lesion **above** the clavicle will be one of trunks or less probably of roots.

(*b*) A lesion **below** the clavicle will be a lesion of cords or nerves.

Lesions above the Clavicle.—The common types are—

1. A paralysis of the **whole plexus.**
2. A paralysis of the **upper part.**

Paralysis of the whole plexus is rarely anatomically and permanently complete. Under general treatment to keep up nutrition as already outlined, and splinting presently to be described, a greater or less degree of recovery is probable in the majority of cases. The findings of the neurologist will aid in an eventual decision for or against operation. It may

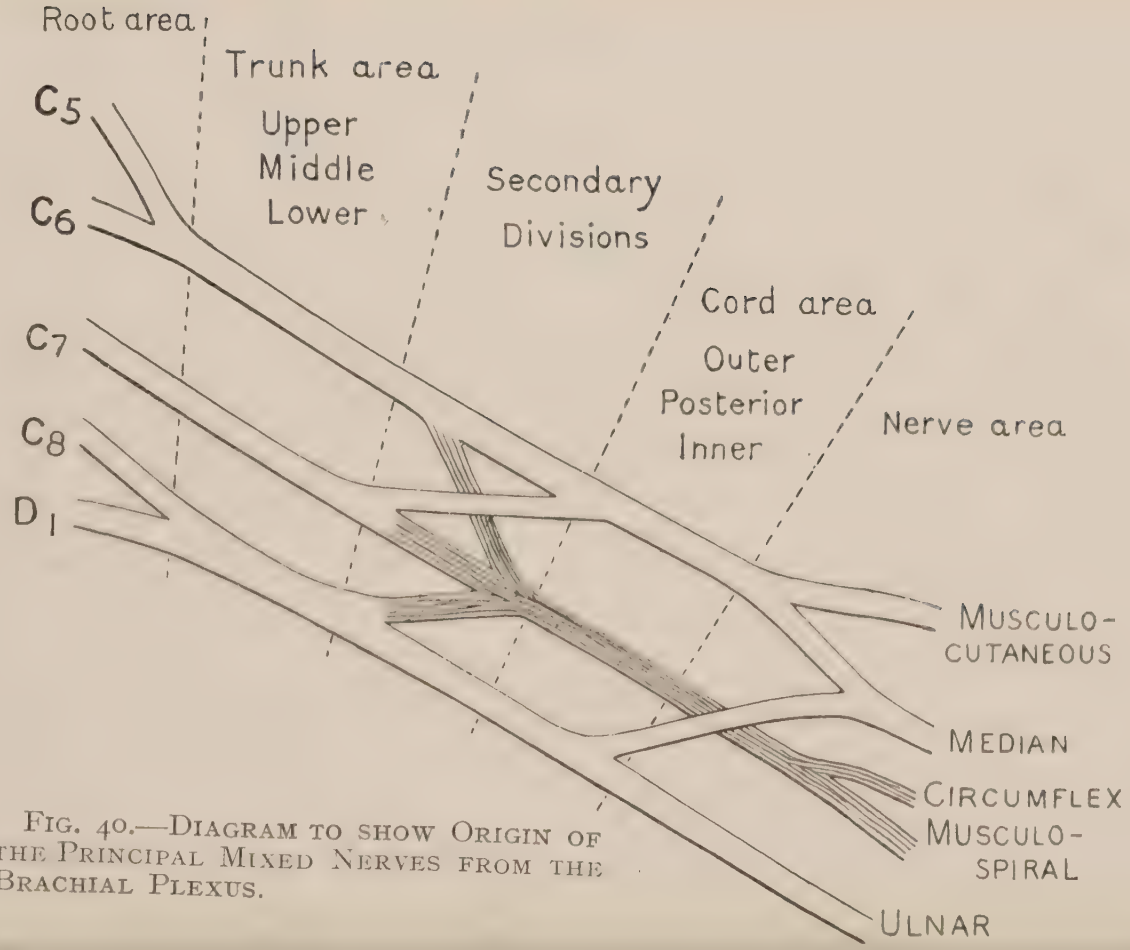

FIG. 40.—DIAGRAM TO SHOW ORIGIN OF THE PRINCIPAL MIXED NERVES FROM THE BRACHIAL PLEXUS.

be found that there is complete division of a part only, which will call for operation. It must be remembered that the paralysis is probably not confined to the nerve fibres actually divided by the projectile. There will be local hæmorrhage and inflammation, usually going on to suppuration with subsequent formation of scar tissue. The immediate inflammation and following scarring will each act in causing interference with the function of nerve fibres not actually divided. This will explain the well-recognised fact that partial paralyses nearly always affect the upper part of the plexus.

A wound through or near the upper trunk will involve that part chiefly.

A wound between the trunks will affect all by inflammation or scarring.

A wound near the lower trunk is likely to damage the subclavian vessels, so that the subject is less likely to survive the injury.

Paralysis of the Upper Part of the Brachial Plexus. Although there is some anatomical variability, the following broad clinical fact must be kept in mind.

The movements of

Abduction of the shoulder,
Flexion of the elbow,
Supination of the forearm,

are innervated by a higher part of the plexus than the opposing movements of

Adduction of the shoulder,
Extension of the elbow,
Pronation of the forearm.

The former group of movements is chiefly, if not entirely, supplied by the fifth cervical root, the latter mainly by the sixth and seventh.

Since the upper trunk is formed from the fifth and sixth roots, a lesion of the fifth root or the upper trunk will affect the first-named group of movements by paralysis of the nerves and muscles producing them. This is the commonest type of supra-clavicular brachial palsy from gunshot wound. The paralysis may not be confined strictly to this group of movements, but loss of power of this group is the dominant feature. Among the muscles paralysed will be the deltoid, flexors of the elbow, and supinators longus and brevis. The arm will hang in a helpless fashion by the side with the forearm pronated in a position reminiscent of Erb's palsy from tearing of the fifth cervical root. Another reason for the predominance of this type of palsy is now evident. The position assumed in this lesion is a position of rest. It is more or less the position which would be taken up in a total but incomplete paralysis of the plexus. The adductors of the shoulder, the extensors of the elbow, and the pronators of the forearm are all relaxed, while the opposing groups are all being stretched. Following the general rule of incomplete palsies, that relaxed muscles recover more quickly than those kept on the stretch, the abductors, flexors, and supinators will be the last to recover. If, therefore, the case has been unsplinted for a time and then examined, the typical palsy referred to will be the most striking feature. This gives the

key to the method of splinting of most cases of supra-clavicular brachial palsy. It is impossible to relax two opposing groups at the same time, so attention should be paid to the most important. The arm must, therefore, be kept abducted, the elbow flexed, and the forearm supinated. Various splints have been devised with this end in view, some clumsy, few absolutely satisfactory. The author recommends for lightness and simplicity the Bandolier Shoulder Splint shown in Fig. 6, p. 42. This fulfils the requirements almost completely, in fact, nearly to the limits of toleration. The splint being applied, it must be retained constantly throughout the period of treatment. Massage, electrical stimulation and warmth are applied, and the functions tested from time to time. The splint must not be removed for any form of treatment. In such a case where operation is somewhat formidable and of doubtful value, the time of probation before operation will naturally be extended, and may well reach to six months before it is deemed advisable to interfere. If at the end of this period there are no signs of recovery and there are indications of a complete division of any important part, operation may be decided on.

The plexus is exposed by an incision from the middle of the posterior edge of the sterno-mastoid muscle to the junction of the outer and middle thirds of the clavicle. The arm and clavicle are pulled downwards, the face turned to the opposite side, and the trunks of the plexus put upon the stretch. The nerves will be found coming out in a row from behind the outer

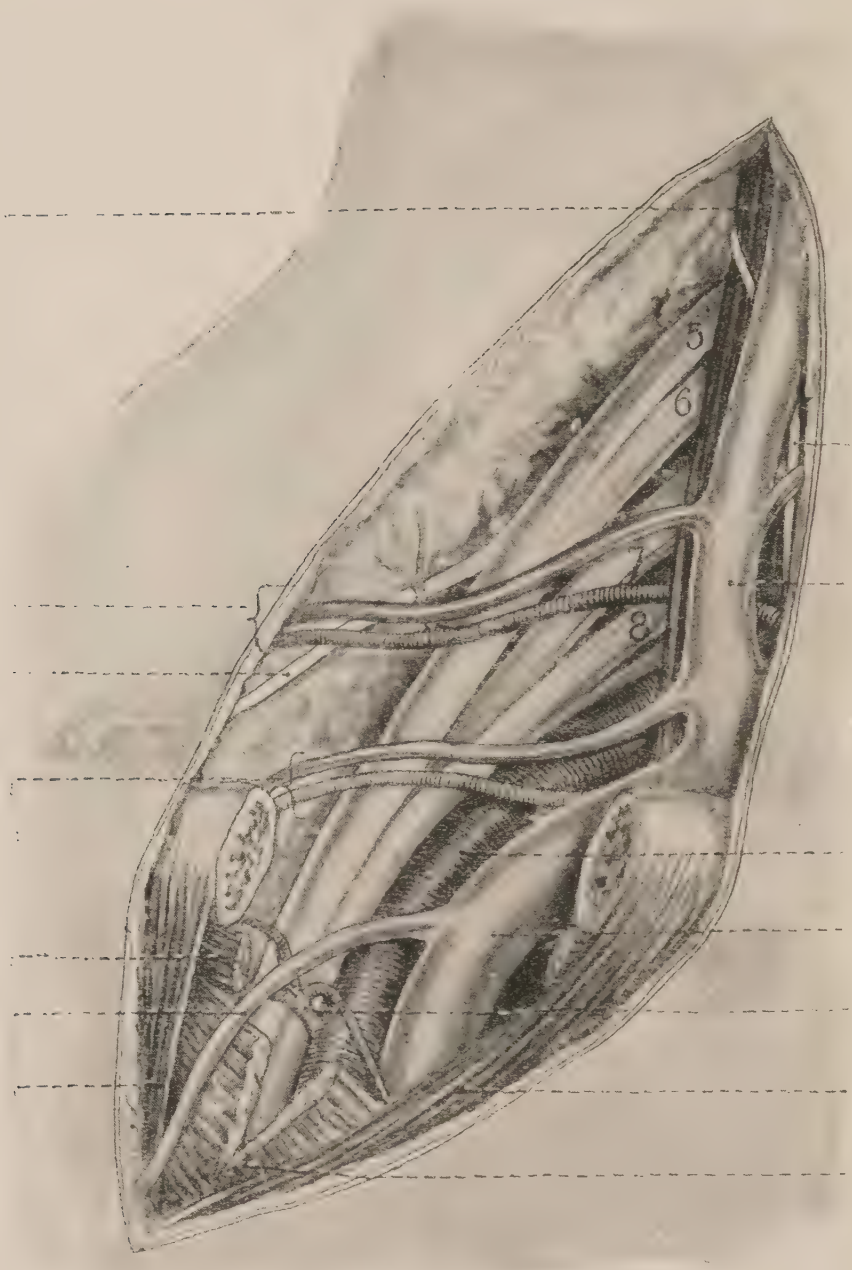

FIG. 41.—EXPOSURE OF THE BRACHIAL PLEXUS.
[From *Nerve Injuries* (Purves Stewart and Evans).

edge of the Scalenus Anticus Muscle (Fig. 41, p. 192). They should be examined from above downwards. If the clavicle gets in the way in reaching the damaged part, its middle third must be turned downwards still attached to the pectoralis. Holes for wiring may conveniently be drilled before division. The Gigli wire saw is recommended. It should be passed very close to the bone. This procedure is a severe one and is rarely needed. If there is such a gap in the upper trunk that the ends cannot be brought together by raising the arm and clavicle, it will be well in this instance to join the peripheral end of the divided trunk to a part of the central end of next trunk. The function of the upper trunk is so much more important that any partial sacrifice of the middle trunk is worth while. In lesions at this high level, localisation of fibres to special muscles is not complete, so that a fairly good result all round may be expected if regeneration takes place.

The patient should be kept in bed with the arm fully abducted for six weeks after operation. After this time, abduction to a right angle will be sufficient. The first signs of motor recovery may be six to twelve months in appearing.

Lesions Below the Clavicle.

Division of the Outer Cord.—This will involve the musculo-cutaneous nerve and the outer head of the median, with resultant paralysis of the flexors of the elbow and some of the muscles supplied by the median in the forearm. There will be loss of sensation

on the outer side of the arm and part of the forearm. During treatment the wrist is slung to the neck to relax the flexors of the elbow. The wrist will fall naturally into the position of flexion and pronation required.

Division of the Inner Cord.—This will chiefly cause

FIG. 42.—INNER CORD PALSY, INCLUDING THAT OF ALL THE FLEXORS OF THE WRIST, THUMB AND FINGERS, AS WELL AS THE INTRINSIC MUSCLES OF THE HAND.

paralysis of the supply of the ulnar and the inner head of the median. Thus there will be paralysis of all the intrinsic muscles of the hand and of some or all of the flexors of the wrist. The wrist will be held extended, and the fingers semiflexed and incapable of full flexion (Fig. 42). The exact proportion of the distribution of function of the two heads of

the median appears to be somewhat variable and difficult to define, especially with regard to the flexors of the wrist supplied by this nerve. Thus division of the outer head may cause partial palsy of the flexors of the wrist, and division of the inner head may give rise to a complete palsy of these groups.

With the inner cord divided there will be loss of sensation on the inner side of the arm and forearm and of the ulnar region of the hand and fingers, *i. e.* the inner finger, half the ring finger and the corresponding portion of the hand. Owing to complexity of distribution of the ulnar nerve, it is difficult to get good relaxation of the various paralysed muscles. In cases where there is some useful movement of the fingers it is, therefore, thought best in this instance to allow the hand to go free, as the tonic contractions of the muscles which are acting will prevent undue stretching of those paralysed. If, however, there is no flexion power of the fingers, and especially if there is any tendency to contracture and shortening of muscles, a splint should be used. One which holds the wrist flexed will relax the flexors of the fingers somewhat. The interossei are relaxed by a splint which flexes the metacarpo-phalangeal joints and extends the inter-phalangeal joints. These positions may be combined by applying a malleable gutter splint to the forearm, hand and fingers, with a gradual bend forward opposite the wrist and a sharp right-angled kink at the metacarpo-phalangeal joints.

Division of the Posterior Cord.—This cord gives off the subscapular and circumflex nerves and continues

as the musculo-spiral. The cord itself is less often divided in the axillæ than the latter nerve. With the whole cord divided there will be paralysis of the muscles of the posterior axillary fold, of abduction of the shoulder and of extension of the elbow, wrist and fingers, and supination of the forearm.

The cord supplies sensation to a strip of skin over the outer side of the shoulder and arm and the back of the forearm, and to the back of the thumb and outer half of the back of the hand. The area of impairment of sensation in the case of division is variable and not of great surgical importance. Splinting to ensure continued relaxation of all the paralysed muscles is a difficult matter, in fact, impracticable, so that it is necessary to attend to those thought most important. Fortunately, this is rare as a complete lesion, and if it is partial it may be possible to relax all the paralysed groups. Considering first the palsy below the elbow, the fingers and wrist must be dorsiflexed, and the forearm supinated. The splint devised by Dr. Cuthbert Morton is admirable for this purpose (Fig. 12, p. 66). The splint is applied to the front of the forearm, wrist and fingers. The portion for the fingers is gently curved to prevent hyper-extension, a very important point, as this condition leads to a very undesirable degree of stiffness. A straight bar points anatomically forward from the inner side of the splint. A neck sling fastened to this keeps the limb in the supinated position. As regards the triceps, if this is paralysed and the deltoid not interfered with, then the limb may

be allowed to hang by the side. If, however, the deltoid is paralysed, it must be considered before the triceps, and the arm must be kept abducted from the side. With the arm in this position it is practically impossible to keep the forearm splinted pointing straight out from the side. The shoulder splint shown in Fig. 6, p. 42 should be used, combined with the wrist splint described above. The elbow must necessarily be kept flexed, except during the daily period of treatment by massage, etc., when it must be extended while the other muscles are kept relaxed as indicated above.

Exposure of the Lower Part of the Brachial Plexus and Axillary Nerves.—The arm must be held in good abduction. The line of incision is that of the axillary artery. If more room upwards is required, the pectoralis muscles must be divided. This may be done as follows. The tendon of the Pectoralis Major is divided near its insertion into the humerus. The muscular origin from the clavicle is next divided and the muscle can then be reflected inwards with its nerve and blood supply intact, and a good view of the nerve trunks is obtained. The Pectoralis Minor is seen crossing the nerves as a muscular strap. This is divided in the line of the nerves, and as much of the costo-coracoid membrane as is necessary. If even yet more room is needed, the clavicle must be divided in the manner indicated in dealing with supra-clavicular lesions, but turned upwards. After the suture of the nerve or nerves, the bony and muscular structures are fastened in their original positions

with very slight interference with their ultimate function.

Lesions of Individual Nerves.—Only those nerves which normally have motor function are likely to need operative treatment. Purely sensory nerves may be sutured in the course of an operation on mixed nerves.

The Musculo-Cutaneous Nerve.—Division will cause paralysis of the flexors of the elbow. The elbow must, therefore, be kept in flexion by a neck-to-wrist sling. The nerve is exposed by being traced downwards as a continuation of the outer cord in the axilla.

The Circumflex Nerve is very rarely divided as such. It is found high in the axilla, leaving the posterior cord to wind outwards behind the neck of the humerus. The deltoid being paralysed, the arm should, of course, be kept on the Shoulder Abduction Splint (Fig. 6, p. 42), throughout the course of treatment.

The Median Nerve.—This important nerve is frequently wounded in any part of its course from the axilla to the hand. It supplies all the muscles of the front of the forearm except the flexor carpi ulnaris and the inner half of the flexor profundus digitorum. In the hand it supplies the abductor and opponens pollicis, half of the flexor brevis pollicis, and the two outer lumbricals. It supplies with sensation the outer two-thirds of the palm and fingers.

With complete division of the nerve in the upper

arm, all the above muscles will be paralysed. Pronation beyond the half-way position is impossible and flexion of the wrist is deviated to the ulnar side. Flexion of the thumb, index and middle fingers is only possible at the metacarpo-phalangeal joints.

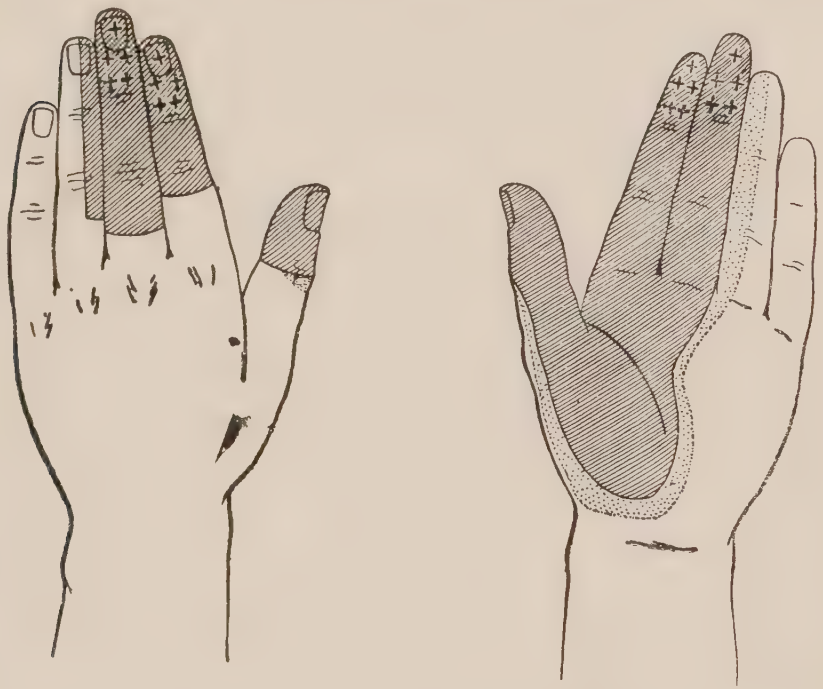

FIG. 43.—MEDIAN PARALYSIS.

The whole area marked out is insensitive to light touch (epicritic loss). The inner deeply shaded area is insensitive also to pin-prick (protopathic loss). The crosses indicate the region where sense of deep pressure is also lost. [Diagram from *Nerve Injuries* (Purves Stewart and Evans).]

Opposition of the thumb and little finger is lost, and the thumb falls back into line with the other digits (*main du singe*). There is impairment of sensation over the front of the outer three and a half digits,

and a corresponding area of the palm, which reaches completeness of loss beyond the first inter-phalangeal joints of the index and middle fingers (Fig. 43, p. 199). It should be remembered that the median supplies sensation to the back as well as the front of the digits to which it is distributed.

When the nerve is divided in the forearm, the muscles of that region usually escape. The loss of motion and sensation in the hand is the same in either case.

Operations on the Median Nerve.—The nerve is exposed in the upper arm in the line of the brachial artery with which it is in close relation. It crosses the artery from without inwards, and at the level of the elbow lies on its inner side. It passes down the middle of the forearm between the superficial and deep flexors and becomes more superficial at the wrist on the inner side of the flexor carpi radialis tendon. It may be exposed here and traced down into the hand and sutured as a good-sized trunk. Higher in the forearm it is more convenient to reach it by retracting the flexor carpi radialis inward.

The Ulnar Nerve.—Division of this nerve is among the commonest of nerve injuries.

It supplies in the forearm the flexor carpi ulnaris and the inner half of the flexor profundus. It supplies all the muscles of the hand except those which are innervated by the median, the group of most importance being the interossei. It supplies sensation to the inner third of the front and back of the hand and fingers.

With complete division in the upper arm, all these muscles are paralysed. If the division is below the elbow, those of the hand alone are usually affected. The typical deformity is due to paralysis of the interossei. All the metacarpo-phalangeal joints are held hyper-extended, and in the ring and little fingers the inter-phalangeal joints are semiflexed. This latter deformity is avoided in the case of the index and middle fingers by the action of the two outer lumbricals which are still intact (Fig. 39, p. 158). The grip of the two inner fingers is defective. The metacarpo-phalangeal joints cannot be flexed with the inter-phalangeal joints extended, and the digits cannot be abducted and adducted. The loss of these movements is due to the interosseous paralysis.

Sensation is interfered with over the inner one and a half fingers, front and back, and the corresponding portion of the hand. The loss is complete only in the little finger (Fig. 44, p. 202).

Splinting in ulnar palsy is not very satisfactory, owing to difficulty in relaxing all the paralysed muscles at once. In the absence of contractures the hand is fairly useful and may well be left unsplinted. If, however, there is a tendency for the ring and little fingers to contract, a splint should be used as described for inner cord palsy.

In the case of either median or ulnar palsy it is especially important to keep the circulation as good as possible by the use of loose, warm gloves or a cotton wool casing for the limb.

Exposure of the Ulnar Nerve.—The nerve lies on

the inner side of the brachial artery in the arm. It passes backward through the internal inter-muscular septum, and crossing the back of the internal epicondyle proceeds straight down the forearm to a point

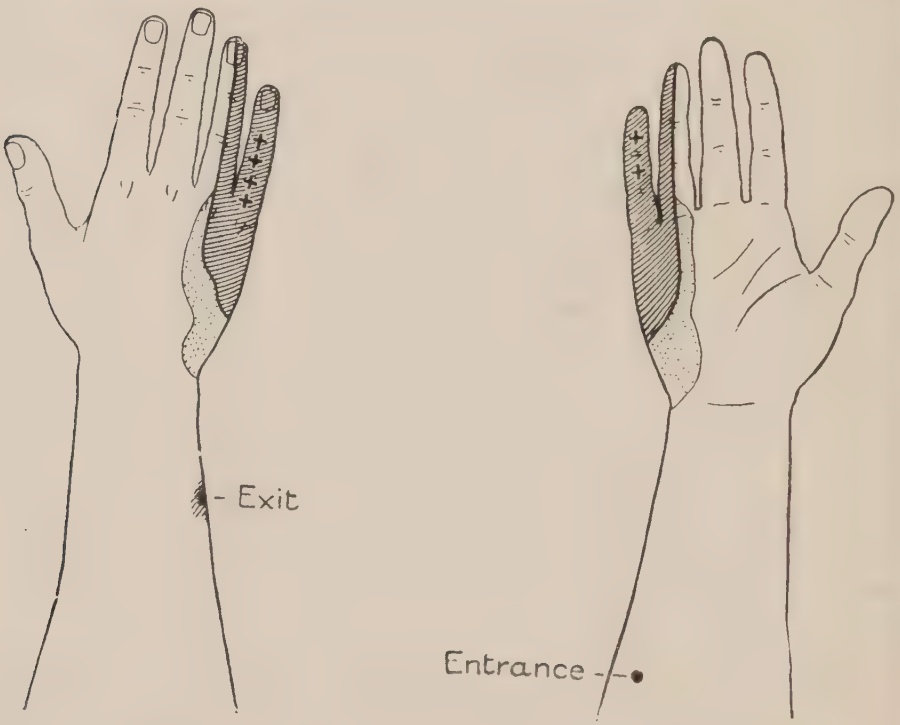

FIG. 44.—ULNAR PARALYSIS.

The whole area marked out is insensitive to light touch (epicritic loss). The inner deeply shaded area is insensitive also to pin-prick (protopathic loss). The crosses indicate the region where sense of deep pressure is also lost. [Diagram from *Nerve Injuries* (Purves Stewart and Evans).]

on the radial side of the pisiform bone. It is displayed on this line in the forearm by retracting the flexor carpi ulnaris inward. Near the wrist it lies on the radial side of the tendon of this muscle which is inserted into the pisiform bone.

The Musculo-Spiral Nerve.—This nerve is very frequently divided or damaged. Owing to its close relation to the humerus it is commonly involved in gunshot fractures of this bone, either immediately or in subsequent callus formation. It is a continuation of the posterior cord of the brachial plexus. It lies behind the axillary, and later the brachial artery, and then winds round the shaft of the humerus in a groove between the inner and outer heads of the triceps muscle. The branches to the triceps are given off at a high level and are usually spared in the division of the nerve.

It reaches the front of the forearm by piercing the external inter-muscular septum about two inches above the elbow joint and passes forward between the supinator longus and brachialis anticus, to the front of the external condyle where it divides into the radial (sensory) and posterior interosseous nerves. The posterior interosseous nerve winds round the neck of the radius between the superficial and deep parts of the supinator brevis, and entering the back of the forearm at once gives off most of its branches, and continues down the back of the forearm as a fine thread. The musculo-spiral and posterior interosseous supply the extensors of the elbow, wrist, and fingers, and the long and short supinators. The musculo spiral also gives a branch to the brachialis anticus which is not of great surgical importance, as its main supply is from the musculo-cutaneous nerve.

Sensation is supplied by cutaneous branches of the musculo spiral to a strip of skin on the outer

side and back of the arm and forearm, and by its radial branch to the outer part of the back of the hand, to the back of the thumb, and to the back of the bases of the index, middle and outer half of the ring fingers.

The degree of paralysis will vary according to the level at which the nerve is divided. The triceps will be spared except in a very high lesion. In division low in the arm the supinator longus may escape. In all cases of division of the main trunk, the supinator brevis and all the extensors of the wrist and fingers will be paralysed, except that the long radial extensor of the wrist might possibly be missed as its branch is given off before the main nerve divides. The usual rule is that the triceps escapes, but the supinators and extensors of the wrist and fingers are paralysed. The sensory loss is variable and usually surgically unimportant. It varies with the level of the division.

If the lesion is above the origin of the external cutaneous branches there will usually be loss of epicritic and protopathic sensation of the dorsum of the thumb and of the outer part of the dorsum of the hand. If the musculo-spiral trunk is divided below the origin of these branches there will be no loss of sensation. If, however, the radial branch is divided at a low level, after inosculation with the external cutaneous branches, there will again be similar loss of sensation (Fig. 45, p. 205).

Splinting to maintain relaxation of the affected muscles is of the greatest importance in the case of this form of palsy. So long as the wrist-drop is

allowed to continue the chances of recovery are very poor indeed. The wrist and fingers must not only be put in the extended position but they must be retained in such without intermission for a moment, as the earliest beginning of recovery of muscle tone is lost at once if the muscles are allowed to be stretched. Splinting is simple and easily maintained. The wrist and hand splint recommended for posterior cord palsy is most suitable here (Fig. 12, p. 66). If supination is unimpaired, the special device to obtain this position is here unnecessary. Usually the forearm is supported by a wrist sling for comfort and convenience, but if the triceps also is paralysed the elbow must be kept extended.

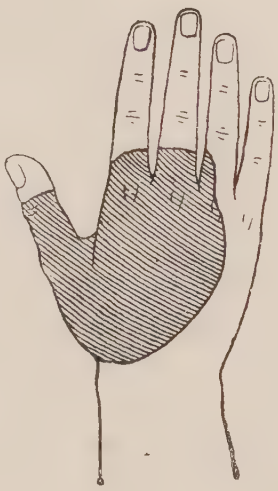

FIG. 45.—SENSORY LOSS ACCOMPANYING A LESION OF THE MUSCULO-SPIRAL NERVE ABOVE THE ORIGIN OF ITS EXTERNAL CUTANEOUS BRANCHES.

[Diagram from *Nerve Injuries* (Purves Stewart and Evans).]

Approach to the Musculo-Spiral and Posterior Interosseous Nerves.—In lesions of the upper end of the nerve the usual axillary incision is made, and the nerve is found behind the axillary or brachial artery. It may be traced downwards if necessary for a short distance round the back of the humerus. More frequently it is necessary to expose the nerve near

its lower end. It is most easily found as it crosses the outer side of the humerus from back to front, about two inches above the elbow. An incision is begun in the groove between the brachialis anticus and supinator longus and should pass obliquely backwards, but almost vertically, round the outer side of the humerus at the point mentioned. The nerve will be found lying between the two muscles. In case of difficulty, it can easily be felt by the finger. It can then be traced either upwards or downwards. If the lesion is below this level the nerve can be traced to the front of the external condyle, where it branches into radial and posterior interosseus. The latter can be traced downwards by reflecting the superficial part of the supinator brevis. As far as the lower part of this muscle the nerve is large enough to make suture practicable, but it is useless to go beyond this, as the nerve breaks up very rapidly and becomes too minute for suture even if it can be found.

More usually the lesion is above the point of exposure. In this case the nerve is traced upwards from the point of exposure until the site of damage is laid bare by cutting directly along the line of the nerve which is nearly vertical. As most injuries are not far from the point where the nerve is exposed as described, this method will be found most generally useful. If, however, the damaged point is somewhere midway between the axilla and the lower end, dissection upward in this way is somewhat clumsy. In these circumstances a great part of the nerve may

be displayed by separating the outer head of the triceps from the posterior border of the deltoid and reflecting the former muscles inward from the bone. This procedure gives a good view of the nerve with a minimum of damage to muscles, vessels, and nerve twigs.

Special Difficulties in the Upper Limb.—In the general section on nerve injuries, the methods of approximating the cut ends of nerves have been described: firstly, by pulling on them by gripping the portions to be removed with artery forceps; secondly by flexion of neighbouring joints; and thirdly, in more troublesome cases by freeing the nerve from its bed above and below. It is only on rare occasions that these devices will fail to obtain good end-to-end suture without tension. The greater the experience of nerve surgery, the fewer will be the failures in this respect. In the case of the ulnar nerve much extra length may sometimes be gained by dislocating the nerve from its position behind the internal condyle, and by allowing it to become joined across the front of the condyle. Cases for this mode of treatment should be carefully chosen, as any violence is likely to damage the twigs going to the flexors just below the elbow-joint. This must be sedulously avoided, and if the procedure cannot be carried out without interference with these branches it must be discarded. Apart from this manœuvre, flexion of the elbow is, of course, useless in the case of the ulnar nerve, and the position of full extension is best.

Speaking generally of unbridgeable gaps in the

upper arm, it should be borne in mind that the limb is practically useless if the hand is useless, and, therefore, strong measures are called for to restore function to the hand. There are three courses open—

(*a*) Shortening of the humerus.

(*b*) Bridging the gap with a nerve graft:

(*c*) Transplantation of tendons in the forearm to restore balance of power.

In the case of the musculo-spiral, the prognosis of end-to-end suture is so good that bone-shortening up to perhaps two inches is recommended. If both median and ulnar cannot be joined the same procedure is advised—that is, if dislocation of the ulnar cannot reduce the problem to one concerning the median alone.

If either median or ulnar is alone affected, then bridging with a nerve graft seems to be the best procedure. A portion of the internal cutaneous or the radial branch of the musculo-spiral may be taken of such a length as to fill the gap without tension. The latter nerve may easily be found by tracing the musculo-spiral between the supinator longus and brachialis anticus down to the elbow. Its removal does not interfere with function. In the case of similar difficulty below the elbow, the same resources are available. Shortening of radius and ulna is not advised, however, but the humerus may be shortened if it will bring the needed result.

It is, fortunately, a very rare occurrence that both median and ulnar cannot be joined, and a nerve graft will usually be applicable to either of these nerves.

As has been stated, the posterior interosseus seldom lends itself to operations of suture, and if this is impracticable from the position of the wound below its extreme upper end, tendon transplantation should be performed as soon as conditions permit.

Shortening of the Humerus.—In the rare cases where this is necessary as indicated above, the operation is best performed by exposing the bone through the lower part of the triceps. The only important structure to avoid is the musculo-spiral nerve in its groove on the back of the humerus. Care should be taken in incising above the lower third of the bone. The ulnar nerve lies well to the inner side and cannot be damaged by an incision in the mid-line down to the bone. Muscles and periosteum are pushed aside and the latter is also stripped from the front of the bone with the rugine. The first division is made with a Gigli saw, the second with any other saw after pulling up the bone with forceps. The operation should be regarded as a distinct one, and fresh gloves should be used if tissues of doubtful asepsis have previously been handled. It is necessary to obtain firm fixation and at the same time to avoid the use of a long bone plate for fear of encroaching on the musculo-spiral area. Two short Lane plates with one hole at each end are, therefore, recommended. The muscle is sutured with catgut and the skin wound closed. The nerve or nerves are next joined end to end, care being taken that they shall not lie in what will subsequently be scar tissue. The arm and forearm are bandaged together in as full flexion as is tolerable,

the wrist is slung to the neck, and the whole limb is then bandaged to the side over a substantial layer of cotton wool. The hand and fingers will, of course, be retained in the form of splint needed for the paralysis. The parts should be kept in position for six weeks. In the case of necessary dressing the limb is unbandaged from the side, and with the wrist sling still in position the patient leans over to the affected side so that the limb hangs free from the trunk. In this way there is very small disturbance of the bone or nerve suture. After six weeks, if the bone union is sound the flexion of the elbow may be very gradually relaxed and gentle massage and electrical stimulation begun. These precautions are necessary for the sake of the nerve suture alone when flexion has been necessary for approximation. In most cases the limb will come straight at a much earlier date, and this is a thing to be on guard against, as it is not possible to believe that the line of union is strong enough to allow the nerve to be stretched, and if the limb goes straight it must be at the expense of the suture line at any early date. Six weeks, then, is the shortest time to allow for union, and even then stretching must be most gradually done.

Tendon Grafting for Irreparable Injury of Musculo-Spiral or Posterior Interosseous Nerve.—The object is to restore a balance between the damaged extensors and unaffected flexors of the wrist and fingers. There must necessarily be a reduction of the power of the flexors, and this is desirable. A moderate degree of power in either direction is far

better than unopposed movements in one direction only.

The following transplantations are suggested—

(*a*) The flexor carpi radialis and flexor carpi ulnaris into the paralysed extensors of thumb and fingers.

(*b*) The pronator radii teres into the long and short radial extensors of the wrist. The operation is thus described by Sir Robert Jones—

"With the forearm midway between pronation and supination an incision is made along the radial border of the forearm in its middle third. Under cover of the tendon of the supinator longus the pronator radii teres will be found where it becomes inserted into the outer border of the radius. From this it is detached, and is then inserted into the tendons of the extensor carpi radialis longus and brevis, which lie closely applied to it on the dorsal surface.

A horseshoe incision, with the convexity resting on the back of the carpus, with the two straight sides extending along the radial and ulnar borders, is now made. Through the lateral aspects of this incision the tendons of the (flexors) carpi ulnaris and radialis are identified, and are detached from their insertion as near the carpus as possible.

The tendons are brought round the ulna and radius respectively in very slanting fashion, and are then attached to the extensors of the fingers and thumb, the carpi ulnaris being attached to the tendons of the three inner fingers and the flexor carpi radialis to those of the thumb and index finger. The method of fixation should be neat and workmanlike."

Paralyses of the Lower Limb.—Interest is practically confined to the division of the sciatic trunk and its

branches. Lesions of the obturator or anterior crural nerves are so uncommon as not to need any special discussion.

The Great Sciatic Nerve.—This nerve trunk, consisting of the external and internal popliteal nerves wrapped in a common sheath, leaves the pelvis by the greater sciatic foramen and passes down on a line roughly along the middle of the back of the thigh. It is covered by the gluteus maximus and biceps femoris muscles, and lies mainly on the adductor magnus. The two component nerves usually separate at the junction of the lower and middle thirds of the thigh, but may be distinct throughout the thigh. The internal popliteal nerve continues straight down the back of the thigh and leg, to end a little beyond the internal malleolus as the internal and external plantar nerves. The external popliteal passes outwards along the lower edge of the biceps, winds round the neck of the fibula, and divides into the musculocutaneous and anterior tibial nerves.

The main sciatic trunk and its branches supply the hamstring muscles and all the muscles below the knee. It supplies sensation to the whole of the leg and foot, except the narrow strip on the inner side, to which the long saphenous branch of the anterior crural is distributed. If, therefore, the whole main nerve trunk at a high level is cut across there will be impairment of sensation over the area indicated, paralysis of the hamstrings and of all the muscles below the knee. More usually, some of the branches to the hamstrings escape, and in any case, there is

always slight power of flexion of the knee, as the gracilis muscle, supplied by the obturator nerve, acts as a flexor.

The foot and toes are quite helpless; the leg and foot somewhat swollen and discoloured during the early stages. Later, in untreated cases, they become dry, shrunken, and stiff in the position induced by gravity, namely, plantar flexion of ankle and toes. The foot flops when the patient walks; and he lifts the limb well by flexion of the hip to clear the ground. If a suitable apparatus is applied to prevent plantar flexion of the ankle the residual disability is remarkably small, and the impairment of the gait might almost pass unnoticed.

The Dropfoot Boot and Splint (Fig. 33, shown on p. 142) are recommended. The stops behind the side irons prevent plantar flexion, and, although the ankle is free to dorsiflexion, the amount of movement in that direction is slight in walking, and the alternate play of flexors and extensors will amount to no more than a small degree of internal massage to the affected muscles. It is impossible to relax flexors and extensors at the same time by any method of splinting, so that an apparatus which prevents undue stretching meets the situation as far as possible.

Owing to the large size of the sciatic trunk, partial division of its fibres is very common, and in fact more so than a complete lesion. It is a remarkable fact that, when this is the case, the paralysis is nearly always of the external popliteal type, with slight, if any, interference with the internal popliteal group. The

descriptions of these two types of injury, which are now to follow, will, therefore, refer to division of the respective groups of fibres either before or after the two trunks have separated from each other at the lower third of the thigh.

FIG. 46.—EXTERNAL POPLITEAL PARALYSIS.

The shaded area shows the extent of anæsthesia to light touch and pin-prick. [Diagram from *Nerve Injuries* (Purves Stewart and Evans).]

External Popliteal Palsy.—In high lesions the short head of the biceps femoris may be paralysed: usually it is spared. There is helplessness of the anterior muscles of the leg and foot (dorsiflexors) and peroneal group (evertors). Sensation is inter-

fered with over part of the outer side of the leg and of the dorsum of the foot, corresponding mainly with the distribution of the cutaneous part of the Musculo-Cutaneous Branch (Fig. 46, p. 214). The foot drops into the position of a paralytic talipes equino varus condition, with the equinus deformity most marked. The patient walks with a gait much like that of total sciatic palsy, but with more noticeable "high stepping." There may be some power of extension of the toes from action of the interossei.

The dropfoot boot and splint is used as in sciatic palsy. Relaxation of the anterior muscles may be made more complete, and the gait in walking further improved, by a modification suggested by Dr. Cuthbert Morton, namely, raising the sole of the boot, and lowering the heel with suitable adjustment of the ankle stop, so that the patient walks with the foot somewhat dorsiflexed. When the boot is off, a Shoe Splint (Fig. 29, p. 130), must be worn constantly.

Anterior Tibial Palsy. — Operations are rarely needed. The paralysis will naturally vary with the height of the lesion. The nerve is found by the line of the corresponding artery, namely the mid-anterior line of the tibio-fibular space. Above and below, the nerve lies on the outer side of the artery, in the intermediate portion in front of it.

Internal Popliteal Palsy.—As an independent lesion, this is rare. The damage to the nerve is usually below the branches to the inner hamstrings.

There is then mainly paralysis of the calf muscles and of those of the sole of the foot, *i. e.* the plantar

flexors and invertors except the tibialis anticus. Sensation is impaired over the lower part of the back of the leg, the sole, and the plantar surface of the toes.

The patient walks in the position of calcaneus, with some valgus, and cannot raise himself on the forepart of the foot owing to the paralysis of the calf muscles.

The heel of the boot should be raised to maintain plantar flexion. An arrangement similar to the drop-foot splint is recommended, but with the stops in front of the side bar, instead of behind, so as to keep the foot from rising to the right-angled position with the leg.

Posterior Tibial Palsy.—The posterior tibial nerve is the continuation of the internal popliteal into the leg. The degree of paralysis of the calf muscles will vary with the level of the lesion. The nerve passes in a straight line from the mid-line in the popliteal space to the back of the inner malleolus. The posterior tibial artery passes behind its upper part from without inward, and then lies along the inner side of the nerve. Exposure is best effected by cutting straight down on this line. Muscle fibres may be split apart, or in the lower part retracted outward.

Operations on the Sciatic and Popliteal Nerves.—If the foot is everted so as to carry the great trochanter backwards and inwards, the line of the sciatic will lie from midway between the back edge of the trochanter and the tuber ischii to the mid-line, in the popliteal space. Incision for its exposure should be on this line, the middle of the incision being crossed by the line between the entry and exit wounds of the projectile.

A long incision is helpful and can do no harm. In its upper part the nerve lies under the gluteus maximus. Here it may be possible to deepen the wound of operation by splitting the gluteus in the line of its fibres. If more room is needed some fibres must be divided. It is essential to get good access to the damaged part. At a lower level the biceps muscle crosses the nerve obliquely from within outwards. It may possibly be retracted sufficiently, but if not it must be divided without hesitation for subsequent suture.

After the nerve has emerged from under cover of the biceps, separation and retraction of muscles alone are needed. The main nerve and its components are so large that they can usually be found with the greatest of ease. If only slight scarring or compression is found, not consistent with the gravity of the symptoms, careful search should be made for a more serious lesion. The former may have been due to spread of suppuration. The internal and external popliteal branches can be found easily, the former as a continuation straight downwards, the latter following the line of the biceps. If a lesion is found on either of these the other must also be examined. In the case of a partial injury of the sciatic trunk, the sheath should be split, so as to separate the external and internal popliteal elements up to the site of the injury.

The amount of individual damage can thus be estimated clearly, and apposition of accurately corresponding groups of fibres made possible. The treatment of the lesion is otherwise on the lines

already laid down under the head of Operative Technique. In doubtful cases, such for instance as when the nerve remains in gross continuity with a local node, it is important to determine if any part remains in nervous continuity. The whole nerve being so large, it is usually easy to dissect from the mass of scar tissue any parts which remain sound. By careful slicing away of the surface of the node, large nerves groups may be seen passing through uninjured except by pressure. These should be carefully preserved. By continuing the dissection, the groups actually divided may be identified and sutured. The method of electrical stimulation of the nerve trunk above the lesion, to find out if any part remains intact, may prove useful; but in the case of this nerve actual dissection is fairly easy and yields more exact results. The nerve trunk can be stretched considerably before the division of intermediate scar, and this combined with flexion of the knee will allow end-to-end union in practically every case.

The sutured nerve need never be laid back in its former bed of scar tissue, and should always be surrounded by healthy muscle. If flexion of the knee has been needed to bring the ends together, the limb must be carefully held during the subsequent proceedings and a splint of the Skeleton Leg-Splint type (Fig. 30, p. 131) applied, acutely flexed at the knee if necessary. Six weeks to two months should be allowed before the gradual relaxation of flexion is begun. Injuries of the popliteal nerves below the level of separation are treated in the same way.

APPENDIX

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Functional Disabilities.

Functional disabilities differ from organic, in that they do not result inevitably from injury or disease. They may be found where there is no history or evidence of either, or they may follow any disease or injury which causes general or local weakness. We are here mainly concerned with those cases in which there has been a definite injury, such as a sprain, or a fracture, or a gunshot wound. Where the functional signs and symptoms are merely an extension of those due to the organic lesion, the diagnosis may be simple: as, for example, when division of a nerve is followed by a paralysis extending beyond the territory of that nerve. Often, however, the organic and the functional are so closely interwoven that diagnosis is very difficult: as when extensive injury near a joint is followed by a limitation in movement which is partly organic and partly functional. While the presence of an organic injury renders the diagnosis of a functional

disability more difficult, it probably makes the outlook for recovery better.

The influences which combine to produce functional disabilities are so numerous and so varied that they cannot be exhaustively discussed here. In many cases there has been some great strain, physical or mental, or both. Prolonged pain or weakness may lead to a faulty attitude or movement which persists as a bad muscle-habit. Or for various reasons (pain, inflammation, splinting, and so on) muscles may have been so long idle that they cannot regain their normal function without training and deliberate effort. Want of knowledge, lack of energy, indifference or hopelessness arising out of the failure of treatment, based on imperfect appreciation of the condition—all tend to confirm the patient in the idea that his weakness or deformity is incurable.

This short and somewhat dogmatic statement is intended to lead up to a consideration of what is hitherto the most promising line of treatment, namely, Muscle Re-education.

The following rules of treatment may be laid down--

1. The patients should not be grouped together, but distributed among the surgical wards. They should not be led to think that there is anything to distinguish them from other surgical cases.

2. The patient should never be allowed to feel that his disability is regarded as trivial, or that he is in any way under a cloud, as though he were either hysterical or a malingerer.

3. Each patient should be examined privately, if possible, and he should not be made to expose his weakness or disability in front of other patients. These men are often very sensitive, and they all need kind and considerate treatment.

4. The patient should be assured that his condition is due to a bad habit of the muscles, and that with training and perseverance it ought to be curable.

Treatment is on the following lines.

Re-education.—As the surgeon proceeds with the examination he carefully explains the condition to the patient, pointing out the nature of the organic lesion, and drawing a clear distinction between any disability resulting from actual damage to the tissues and such as is purely functional. He will often need to explain in a general way the anatomy of the part, and to demonstrate, first, the normal action of the muscles in a sound limb, and then the faulty action of the muscles in the part affected. He must make the patient understand how his injury has inevitably led to certain of the signs and symptoms, but can never have given rise to the others; and he must convince him that through shock, disuse, or otherwise, certain muscles have fallen into bad habits, which ought, however, to be overcome by careful training and perseverance. If there is **spasm,** the surgeon shows which muscles are at fault, and tries to induce the patient, first, to relax these (or, it may be, all the muscles of the limb), and then to make gentle movements, now towards the spasm and again in the

opposite direction. If possible, complete relaxation should be secured in the first lesson, but too much must never be attempted at a sitting, and as soon as there are signs of real fatigue the lesson must be stopped. Splints to stretch contracted muscles (as also to support flaccid ones) are just as necessary in the early stages of the treatment of functional disabilities as in organic lesions. They will be of the types already described. In **inco-ordination** the patient usually makes desperate attempts to carry out the desired movement, but he must be taught to relax the whole limb, and then to execute some simple movement which involves the proper use of a single muscle, or group of muscles, usually that which has not been doing its part. From this simple movement he gradually advances to others which are more and more complicated, until he has obtained complete mastery over all the muscles. Inco-ordination often means that he is merely using normal groups of muscles in an abnormal way. It may be only the sequence which is wrong, or perhaps one group is being checked because its antagonists insist on pulling. **Flaccidity** is dealt with by showing that the muscles in question are still able to contract. This is often a great surprise to the patient, and besides giving him confidence it stimulates the tracts of muscle-sense, and so, as it were, reminds the brain of its forgotten powers. Contraction may be obtained by faradism or by various forms of mechanical stimulation, such as flagellation, excitation, and so on.

Faradism may be applied with one of the terminals

over the flaccid group, or by using the faradic bath. It should be noted that the faradic bath may be harmful if it stimulates and strengthens the unaffected muscles at the expense of the flaccid group. This may be avoided by simultaneous faradism in which a separate current is applied to each group and graduated accordingly. Faradism may be useful in restoring the circulation and muscle tone, and **massage** may be employed for the same purpose.

Flagellation consists of a series of rapid taps with something light and flat, like a stiff razor-strop. Smartly done, it causes reddening of the surface and often rouses reflex or voluntary contraction.

Reflex Excitation is a most valuable form of treatment. If, for example, the flexors of the elbow are not acting, the joint is first smartly flexed by the surgeon and then smartly extended, the patient being asked to help in the movements as much as possible. This alternate smart stretching and relaxing of the antagonistic flexors and extensors can hardly be borne with entire passivity by the patient, and sooner or later he almost unconsciously helps or resists. Thus if the flexing movement while still incomplete is suddenly stopped by the surgeon, the flaccid group of flexors may feebly carry it on. When once the patient has seen and felt the affected muscles contracting, he gains confidence; and with further training and practice often makes rapid progress. In this, as in all cases, it is well to stop short of fatigue, and to be content if necessary with a little gain in the early stages. Where the muscles are too enfeebled

for such vigorous treatment the exercise should be as follows: If the foot, for example, is dropped and inverted through wasting and weakness of the anterior crural group of muscles and peronei, the surgeon should flex the ankle fully against gravity, and then gently allow gravity to extend it. The passive flexion relaxes the flaccid muscles, and the gentle extension then stimulates them to contract; and this contraction (if it takes place) may either be so feeble as merely to cause a flickering of the tendons of one or more of the muscles, or it may be so strong that the foot is actually maintained in flexion for a few seconds, and then gradually allowed to fall. Where the patient will tolerate it, painful stimulation is a great help. Thus, where there is complete flaccidity of the whole foot, if the toes be somewhat roughly over-extended or squeezed together from side to side, muscle after muscle may begin to pull with surprising speed and power, and a man who has hobbled about on crutches for months may, after a day or two, be able to walk without either splint or stick. Where there is cutaneous and deep anæsthesia of the foot, and the patient can tolerate the roughest treatment possible without pain, so that reflex contraction is difficult to stimulate, and when stimulated cannot be felt, the outlook for recovery is never very bright.

Exercises should all be carefully graduated, and in the later stages they may be of the gymnastic type. Occupation in curative workshops will be of the greatest value after voluntary power has become definitely established, and if the occupation brings

the affected muscles into play—thus, driving a treadle machine may help a recovering footdrop.

The results obtained by the foregoing methods have often been remarkable. Patients with a disability extending over one or two years, and even more, have been cured, or practically cured, in a few minutes. Other cases, including the majority, respond more slowly, and a certain number do not react to treatment at all. The first group will probably be fit for further military duty of some kind; the second will usually be greatly benefited, and enabled sooner or later to return to full civil employment; the last should, generally speaking, be given a fair trial in hospital say for three months, and should then be discharged, wearing a retaining or supporting appliance, such as would be suitable if the disorder were organic and incurable. The ultimate result in such cases cannot yet be predicted.

It will be seen that the procedure of re-education is essentially straightforward and free from any element of mystery or psycho-therapy. There is no subjection of the patient's will, as in hypnosis or treatment by suggestion. The method tends wholly in the direction of retaining and restoring the patient's self-respect, giving him hope and encouraging him to regain his self-control.

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